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Canadian Framework for Collaboration on Groundwater

2003

Canada

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Prepared by:

Alfonso Rivera
Natural Resources Canada

Allan Crowe
Environment Canada

Al Kohut
British Columbia Ministry of Water,
Land, and Air Protection

Dave Rudolph
University of Waterloo

Cam Baker
Ontario Ministry of Northern
Development and Mines

Darryl Pupek
New Brunswick Department of
Environment and Local Government

Nolan Shaheen
Saskatchewan Water Corporation

Maurice Lewis [1]
Canadian Ground Water Association

Kevin Parks
Alberta Energy and Utilities Board

[1]Deceased

NOTE: *The concepts and ideas presented in this framework are the responsibility of the members of the National Ad Hoc Committee on Groundwater and do not necessarily represent the views of any government or nongovernment agency. This document is a working draft for discussion purposes; it has not been reviewed or approved by any of the agencies from which the members of the National Ad Hoc Committee were drawn.*

Questions regarding this document should be addressed to: Alfonso Rivera, Chairman, National Ad Hoc Committee on Groundwater, Geological Survey of Canada–Quebec, Natural Resources Canada, 880, Chemin Sainte-Foy, Suite 840, Québec, Quebec G1S 2L2, Tel. (418) 654–2688, E-mail arivera@nrcan.gc.ca.

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3303-33rd Street N.W.
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101-605 Robson Street
Vancouver, B.C. V6B 5J3

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Preface

Unlike surface water, groundwater is largely invisible to most people. Because of this, groundwater presents some very significant challenges in terms of understanding how it flows through the subsurface, how much there is, how much we can safely extract, and what are the limitations of the resource. Some issues that affect groundwater as a resource include its sustainability with respect to both human use and ecosystems, climate change, and contamination.

The Canadian Framework for Collaboration on Groundwater is the result of joint work carried out by a large number of organizations represented by a national ad hoc committee. It was an initiative of the Geological Survey of Canada (Earth Sciences Sector, Natural Resources Canada) based on recommendations from the First National Workshop on Groundwater that was held in 2000 in Québec. The National Ad Hoc Committee on Groundwater was formed to develop a vision, an action plan, and a mechanism to promote, communicate, and implement the framework for collaboration.

The draft framework was discussed by a broad range of stakeholders from all levels of government, academia, and the private sector in a Second National Workshop on Groundwater held in Calgary in 2001. During that workshop, a consensus was reached on the document's content and the national ad hoc committee was given the task to refine and publish the document.

The extensive consultation and the broad consensus on the Framework established the viability of this vision, and I am confident that it can be achieved. As I write this, some activities are already underway and the Framework is having some impact on renewing water policies and developing agreements between federal and provincial governments and stakeholders. Many of the stakeholders have plans to adopt the vision of the Framework, to do an inventory of the groundwater resources of Canada, to share information, to generate national databases on groundwater that are easily accessible, and to fill in the gaps in groundwater knowledge identified in the two national workshops.

The recommendations in this document are aligned with a long-term vision and mission to fill gaps in the knowledge of the country's groundwater resources. The Framework recognizes and strongly emphasizes the need to address the groundwater issues of Canada through close co-operation between federal, provincial, territorial, municipal, and First Nation governments.

The development of the Canadian Framework for Collaboration on Groundwater is an important step in furthering the understanding of our groundwater resources, and I would like to thank and congratulate the many stakeholders who have contributed to this Framework. Natural Resources Canada has been pleased to co-ordinate and participate in this effort.

Susan M. Till
Associate Assistant Deputy Minister
Earth Sciences Sector
Natural Resources Canada

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EXECUTIVE SUMMARY

Close to ten million Canadians rely on groundwater for their drinking-water supply. All Canadians rely indirectly on groundwater because it is the primary source of water for livestock watering and crop irrigation. As groundwater is an integral component of the hydrological cycle, the health of our streams, lakes, wetlands, and associated ecosystems depends upon groundwater. Groundwater also sustains economic activity by pro viding significant water supplies for industries involved in manufacturing, mining, and petroleum. Although groundwater is a renewable resource, it is not limitless and requires wise management to protect its integ rity, security, and sustainability.

Availability and quality of groundwater throughout Canada are under significant stress due to increasing demand, contamination from intensified land-use activities, and potential variations in recharge patterns due to climate-change impacts. In recent years, it has become clear that, due to financial restrictions, the requirement for multidisciplinary expertise, and the interjurisdictional nature of groundwater, no single agency is able to adequately address all related issues. The only way to successfully manage Canada's groundwater resources is through close intergovernmental and stakeholder co-operation. Because groundwater condi tions and issues can be very complex and expensive to investigate, exploring avenues for sharing of information, new knowledge, and technological advances is an important economic consideration for agencies and stakeholders.

Canadian Framework for Collaboration on Groundwater

There is a history of intergovernmental co-operation on groundwater issues throughout Canada that continues to this day. Notably lacking, however, is a commonly shared vision about how to manage Canada's groundwater resources to ensure that all Canadians have access to clean and sustainable groundwater. The **Canadian Framework for Collaboration on Groundwater** (herein called 'the Framework') defines that vision. This framework forms a basis for securing the fundamental information necessary to manage and protect the groundwater resource, and must be implemented collaboratively. As policy makers move ahead to define the guidelines for long-term management of groundwater, the Framework structure will provide immediate access to the current science and technology in support of policy design. The Framework respects the jurisdictional responsibilities of each level of government in all provinces and territories of Canada. It also recognizes the contribution of universities, industry, and other stakeholders.

Vision and mission statements

The Framework's **vision** for groundwater is:

> ***To ensure a healthy and sustained groundwater resource for all Canadians.***

The Framework's **mission** will be:

> ***To improve the knowledge base of Canada's groundwater resources and make that information readily available to assist all levels of government, communities, industries, and individuals in making timely and informed decisions to protect, manage, and sustain Canada's groundwater resources.***

Goals and objectives

The general goals for the *Canadian Framework for Collaboration on Groundwater* are focused on:

- acquiring a high standard of groundwater information and knowledge;
- improving communications and collaboration among all agencies and organizations involved in groundwater activities;
- establishing effective linkages of groundwater-information systems; and
- providing a resource base accessible to all levels of government for the development of groundwater-management policy.

Achieving these fundamental goals will assist all shareholders in managing groundwater resources in a more effective and sustainable manner, while simultaneously increasing public awareness of the importance of this valuable resource in the long term. These goals will be addressed through a series of national co-operative programs.

National co-operative programs

Across Canada, the complex and diverse issues related to management of the country's groundwater resources are normally handled on a provincial basis. Many of these issues, however, are common throughout Canada and could be effectively co-ordinated through a series of national co-operative programs.

Canadian expertise in groundwater management is internationally recognized. One of the primary benefits of initiating these co-operative programs on a national basis will be to organize the available expertise in such a way that it be accessible to all stakeholders.

The Framework identifies a series of national co-operative programs that were recommended at the recent national groundwater workshops, held in Québec in 2000 and in Calgary in 2001, as being of the highest priority to Canadians. These national programs fall within four groups:

- Applications of existing expertise and technology (e.g. inventory of national groundwater resources, monitoring)
- Issues requiring additional scientific research
- Improved accessibility to groundwater data and information
- Training and accreditation

Benefits of national co-operative programs

- Financial
- Improved knowledge
- Access to expertise

Co-ordination and collaboration mechanism

Following the recommendations put forth through the national workshops, a proposed mechanism for co-ordination and collaboration within the framework initiative was centred on a **Canadian Groundwater Advisory Council (CGAC)**. This council would be formed from the primary groups that have interests and roles in the management of groundwater in Canada. For example, the groups would include various levels of government, nongovernment groups, industry, and universities. The principal roles of CGAC would be to identify looming issues, provide advice, and implement the Framework. This council does not regulate.

The CGAC would advise a **Federal-Provincial Groundwater Committee (FPGC)**. This committee would consist of representatives from the provincial governments, the federal government, and the Yukon Territory. The main mandate of this committee would be the implementation of the national co-operative programs and guidelines. This committee would have strong links to government and links to the Canadian Council of Ministers of Environment (CCME) and the National Geological Surveys Committee (NGSC).

A secretariat office would support both CGAC and FPGC. This office will establish an effective communications plan, including a Web site, publish the work of the data-model teams, and seek out and administer funding to support CGAC initiatives.

A series of working groups could be established by the CGAC, as required, to deal with various aspects of the Framework. This may include, for example, the preparation and communication of appropriate scientific information requested in support of specific policy development or in response to a technical issue of national relevance.

It is clearly recognized that, because Canada's groundwater issues and priorities may change with time, the framework must be flexible to recognize and adapt to these changes.

Next steps

In consideration of the growing public concern and enhanced government interest in groundwater, a number of issues of national importance must be addressed to ensure the protection and sustainability of Canada's groundwater resources. The next steps to implement the

framework are focused in four areas: 1) co-ordination and collaboration mechanisms; 2) national co-operative programs; 3) communication; and 4) performance standards and uniformity across Canada.

With respect to co-ordination and collaboration mechanisms, the next steps are to:

- establish a Federal-Provincial Groundwater Committee (FPGC) to enhance co-operation among all levels of government;
- establish a Canadian Groundwater Advisory Committee (CGAC), representing various stakeholders, to advise the FPGC; and
- carry out annual reporting of the progress of the CGAC (FPGC) to stakeholders.

With respect to national co-operative programs, the next steps are to:

- enhance funding for groundwater research and inventory;
- undertake an assessment and inventory of Canada's groundwater resources;
- establish a groundwater-monitoring 'network of networks';
- identify critical needs for research on Canadian groundwater issues; and
- promote linkages between government policy and the research community.

With respect to communication, the next steps are to:

- initiate programs for raising awareness of the public on their role in protecting groundwater resources;
- provide a knowledge source of groundwater information for groundwater professionals and the public;
- develop and promote an electronic national groundwater forum; and
- continue to hold national groundwater workshops every two years.

With respect to performance standards and uniformity across Canada, the next steps are to:

- provide advanced training to enhance knowledge and skills of groundwater professionals, well drillers, and technicians;
- provide accreditation for groundwater professionals, well drillers, and technicians;
- promote acceptance of provincial accreditation of groundwater professionals, well drillers, and technicians across Canada; and
- develop, promote, and co-ordinate guidelines for best-management practices and technology transfer.

1 INTRODUCTION

Ten million Canadians rely on groundwater for their drinking-water supply. All Canadians rely indirectly on groundwater because it is the dominant source of water for livestock watering and crop irrigation. The health of our streams, lakes, and wetlands depends upon groundwater because it is an integral component of the hydrological cycle. Groundwater also sustains economic activity and provides significant water supplies for industries involved in manufacturing, mining, and petroleum. Although groundwater is a renewable resource, wise management is required to protect its integrity, security, and sustainability.

Canada's valuable groundwater resources are very significant, but groundwater is less known and understood than surface water because it is hidden from view. In contrast to other developed nations (United States National Research Council, 2000), Canada does not have a current and comprehensive national-scale inventory of its groundwater resources. The most recent national assessment was published by the Geological Survey of Canada in 1967 (Brown, 1967); however, several regional studies have been undertaken since then (*see* section 5.5). Availability and quality of groundwater throughout Canada are being increasingly threatened by overexploitation due to population growth; contamination from intensified industrial, agricultural, and resource development; and decreased recharge due to climate-change impacts. In recent years, it has become clear that, due to financial restrictions, the multidisciplinary knowledge required, and interjurisdictional issues, the only way to successfully address these stresses on Canada's groundwater resources is through close co-operation between federal, provincial, territorial, municipal, and First Nation governments.

This document identifies goals and outlines strategic directions toward an interagency **Canadian Framework for Collaboration on Groundwater**. The framework is not intended to be a detailed implementation plan that will provide solutions to all groundwater issues in the country. Rather, it forms a basis for securing the fundamental information necessary to manage and protect the resource, and for obtaining the collaborative insight, participation, and guidance of partners and stakeholders to develop the key ideas, concepts, and programs that can be strategically implemented over time.

The Framework's **vision** for groundwater is:

To ensure a healthy and sustained groundwater resource for all Canadians.

The Framework's **mission** will be:

To improve the knowledge base of Canada's groundwater resources and make that information readily available to assist all levels of government, communities, industries, and individuals in making timely and informed decisions to protect, manage, and sustain Canada's groundwater resources.

There is a history of intergovernmental co-operation on groundwater issues throughout Canada that continues to this day. Notably lacking, however, is a commonly shared vision about how to manage Canada's groundwater resources to ensure that all Canadians have access to clean and sustainable groundwater. During the past decade, there have been several initiatives to define a national groundwater strategy and interjurisdictional co-ordination, including those of Gilliland (1990), the Canadian Geoscience Council (Morgan, 1993), and Karvinen and McAllister (1994). These studies identified gaps in interjurisdictional collaboration, public awareness, scientific knowledge, national standards, awareness of future demands, and assessment of the resource. They also provided recommendations for co-operation, co-ordination, exchange of information on groundwater, and increasing knowledge of groundwater at a national level.

These initiatives, however, did not provide a mechanism or framework within which the recommendations resulting from collaboration and co-operation at a national level could be implemented. At a recent national workshop on groundwater (Rivera, 2000), which was attended by groundwater personnel from all provinces, several federal departments, and numerous stakeholder groups, the groundwater issues were again identified and the need for interjurisdictional collaboration and co-operation was again strongly stated and supported by all attendees. Recent events have shaken the public's confidence in the viability of groundwater as a safe and secure source of water, and their demand for action from all levels of government has never been higher. What was stated in the Federal Water Inquiry of 1985 (Pearse et al., 1985), that the public is not interested in what level of government does what but only that effective action is taken, is even more true today. Never before has the need and the desire for a national groundwater strategy (perceived as a framework for collaboration) been greater.

The Canadian Framework for Collaboration on Groundwater discussed here builds on the findings and recommendations of these earlier groundwater initiatives, reports, and workshops.

A Canadian Framework for Collaboration on Groundwater is needed now for a number of reasons:

- Groundwater is likely to become a strategic national resource in Canada.
- Canada does not have a current national-scale inventory of its groundwater resources.
- A majority of the populace is unaware of the value and importance of groundwater resources.
- Funding for groundwater research and inventory has been severely constrained during the past decade.
- There is an acute need to assess the groundwater resources of Canada at regional and national scales.
- There are emerging groundwater quantity and quality issues in all regions of the country.
- There are significant gaps in our knowledge of groundwater resources.
- There is a lack of co-ordination between levels of government and intergovernmental agencies dealing with groundwater issues.
- Increasing demands and costs to secure clean water, and decreasing availability in some areas, have important consequences for future economic growth.

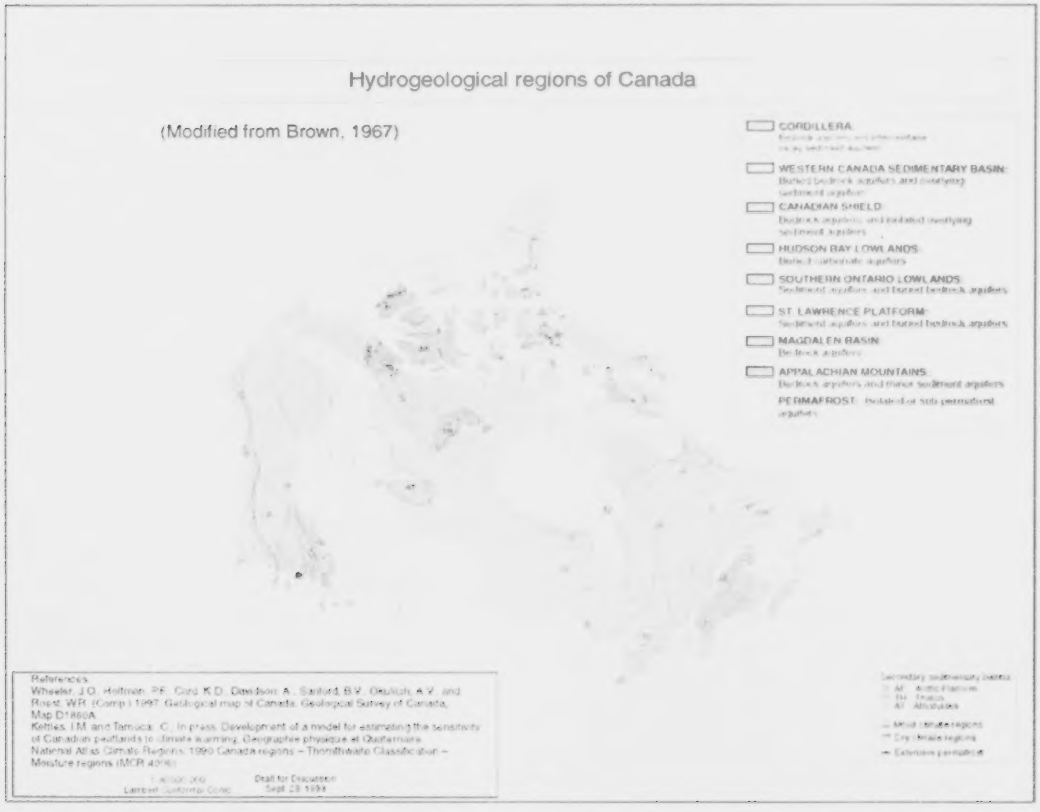
The purpose of the *Canadian Framework for Collaboration on Groundwater* outlined in this document is to:

- set specific goals and objectives to be achieved, and identify the agencies, partnerships, resources, and actions required to meet these goals and objectives;
- provide the general direction and key actions needed in the next 10 years to improve the management and protection of the groundwater resources of Canada for the social, environmental, and economic well-being of all Canadians;
- provide a mechanism to facilitate synergy and co-operation in groundwater studies in Canada; and
- identify the general roles and responsibilities for the agencies and groups who will implement the Framework.

2 BACKGROUND

2.1 First National Workshop on Groundwater (2000)

In June 2000, a national workshop on groundwater, initiated by the Geological Survey of Canada (Rivera, 2000), was held in Québec. It was attended by representatives from most provincial and territorial departments responsible for groundwater management, Environment Canada, Agriculture and Agri-Food Canada, Indian and Northern Affairs Canada, and Health Canada. Representatives from academia, industry, and scientific associations (such as the University of Waterloo, Canadian Ground Water Association, and International Association of Hydrogeologists, respectively) also attended. The workshop identified issues relating to Canada's groundwater, and explored various means for addressing them. Representatives stressed the importance of understanding the country's groundwater quantity and quality, and expressed the need for better co-ordination and collaboration at the federal level, and between federal and provincial agencies. The creation of an advisory or co-ordinating committee, which would include federal and provincial agencies and other representatives, was suggested.


Hydrogeological regions of Canada
(Modified from Brown, 1967)
CORDILLERA:
WESTERN CANADA SEDIMENTARY BASIN:
CANADIAN SHIELD:
HUDSON BAY LOWLANDS:
SOUTHERN ONTARIO LOWLANDS:
ST. LAWRENCE PLATFORM:
MAGDALEN BASIN:
APPALACHIAN MOUNTAINS:
PERMAFROST:
References:
Wheeler, J.O., Hoffman, P.F., Card, K.D., Davidson, A., Sanford, B.V., Okulitch, A.V., and Roest, W.R. (Comp.) 1997. Geological map of Canada. Geological Survey of Canada, Map D1860A.
Kettles, I.M. and Tarnocai, C., In press. Development of a model for estimating the sensitivity of Canadian peatlands to climate warming. Géographie physique et Quaternaire.
National Atlas Climate Regions: 1960 Canada regions – Thornthwaite Classification – Moisture regions (MCR 4016)
Draft for Discussion
Sept. 28 1994

It was recognized, at the workshop, that there is a knowledge gap related to the protection, delineation, characterization, and dynamics of Canada's main aquifers. The aquifers may either be under stress with respect to quality and quantity, or could be at the limit of the natural cycle of replenishment. As antici pated, the workshop significantly contributed to a better understanding of the knowledge gaps with respect to groundwater in Canada, and of the opportunities to address common issues.

The meeting was used to define orientations for co-operation and identify priorities of groundwater research. It also provided a basis for establishing a Canadian framework for collaboration on groundwater, as well as developing partnerships to address the existing knowledge gaps. Appendix 1 presents a succinct overview of the emerging groundwater issues, identified on a province-by-province basis.

One of the most significant recommendations by the participants at the workshop was to create a structure for a national committee to focus on groundwater issues. In light of this recommendation, the Geological Survey of Canada facilitated the creation of a national steering committee to foster groundwater studies at the national level. As a first step, a temporary National Ad Hoc Committee on Groundwater was established to develop a first draft of a Canadian Framework for Collaboration on Groundwater (herein called 'the Framework'), and to promote the Framework to interested federal and provincial departments, and other stakeholders (the members of this committee are listed in Appendix 2). It was envisioned that the final version of the Framework would be prepared through the more formal structure outlined in this draft.

2.2 Second National Workshop on Groundwater (2001)

Since May 2001, a National Ad Hoc Committee from federal and provincial government agencies, uni versities, and industry drafted a common framework for co-operation and collaboration on groundwater studies across Canada. This followed one of the main recommendations of the First National Workshop on Groundwater. The committee organized the Second National Workshop on Ground water, held in Calgary on September 20 and 21, 2001, where the draft document on the framework was submitted for discussion (Rivera, 2001).

The Second National Workshop on Groundwater represented the inaugural presentation to the groundwater community of the Canadian Framework for Collaboration on Groundwater that resulted from these efforts. This workshop debated the contents of the draft strategy produced by the National Ad Hoc Committee, and sought consensus from participants.

The main objectives of the workshop were to 1) present the draft document on the Framework; 2) discuss the recommendations presented in the document; and 3) obtain consensus on a structure for a groundwater advisory council, a framework for collaboration, and delineation of co-operative projects.

About 70 delegates attended the workshop, studied the recommendations, and decided on actions that will have an impact on the management and protection of this priceless resource. Representatives from each province, the Yukon Territory, and four federal agencies helped fine-tune both the framework for collaboration and the permanent mechanism to implement it.

The main outcomes of the workshop were the following:

- There was general agreement on the proposed Canadian Framework for Collaboration on Groundwater. Representatives from various organizations indicated a strong support and their willingness to participate. The document, as it was presented, should be revised in accordance with the workshop discussions.
- It was agreed that the document, after revision, should be addressed to governments for endorsement and development of co-operative programs.
- The structure proposed for a Canadian Groundwater Advisory Council was accepted, with suggestions for modifications to the executive committee.

This report represents the finalized document of the extended National Ad Hoc Committee.

3 PRINCIPLES

Recognizing that the provinces have the major legislative-constitutional responsibility for water, including groundwater, the federal government has a very unique role to play in both expanding the public's understanding of this national resource and co-ordinating a collaborative approach to the management of the unique spectrum of groundwater-related problems that are encountered throughout the country. The roles of the provincial and federal governments are respected in this proposed framework, the emphasis of which is placed on the benefits of a co-operative effort among levels of governments, partners, and stakeholders.

The proposed Canadian Framework for Collaboration on Groundwater is based on the following principles:

- The Framework respects the jurisdictional responsibilities of each level of government in all provinces and territories of Canada.
- The Framework will address the groundwater quantity and quality priorities in each jurisdiction, so as to include regional concerns.
- The Framework will develop partnerships and promote groundwater stewardship with communities and agencies.
- Programs will be developed co-operatively and, where possible, will be jointly delivered by the participating agencies.
- The Framework recognizes the geographic and bioclimatic diversity of various regions of Canada.
- Groundwater knowledge will be shared and made readily available to all parties.

In consideration of growing public concern, several provincial and federal agencies have identified a number of groundwater issues that need to be addressed within a national scope (Appendix 1). Provincial ministries of environment and other provincial agencies, as well as federal agencies such as Natural Resources Canada and Environment Canada, have expertise in groundwater studies. A number of universities and industry groups have expertise in groundwater research and groundwater development, respectively. Co-operation and collaboration among all of these agencies will form the core of an effective Canadian Framework for Collaboration on Groundwater.

4 GOALS, OBJECTIVES, AND POTENTIAL OUTCOMES

The general goals for the Canadian Framework for Collaboration on Groundwater are to:

- acquire a high standard of groundwater information and knowledge;
- improve communications and collaboration among all agencies involved in groundwater activities; and
- establish effective linkages of groundwater-information systems;
- provide a resource base accessible to all levels of government for the development of groundwater-management policy.

Achieving these fundamental steps will assist all levels of government, communities, industries, and individuals in making timely and informed decisions regarding protection and management of groundwater resources.

The specific goals for the Framework are to:

- provide information to all stakeholders on the status and trends of groundwater quality and quantity, in order to support sustainable management of groundwater resources;
- inventory and characterize, by the year 2012, the groundwater resource in priority areas of Canada, in terms of its quantity, quality, vulnerability, dynamics, and sustainability;
- establish and build on existing groundwater-monitoring networks to achieve a 'network of networks';
- create a national permanent mechanism to foster and advocate groundwater as a national strategic resource in Canada, including mechanisms for interjurisdictional co-ordination;
- provide improved public access to groundwater information, and develop groundwater education and public-awareness initiatives; and
- develop, promote, and co-ordinate guidelines (for monitoring, aquifer-classification maps, and aquifer-vulnerability areas, and to support best-management practices).

The short-term actions (next 12 months) are to:

- produce the final draft of the Framework document, submit it to partners and stakeholders nation wide, promote it, develop a business plan, and seek endorsement from all levels of government;
- identify potential funding sources for groundwater programs and solicit funding support;

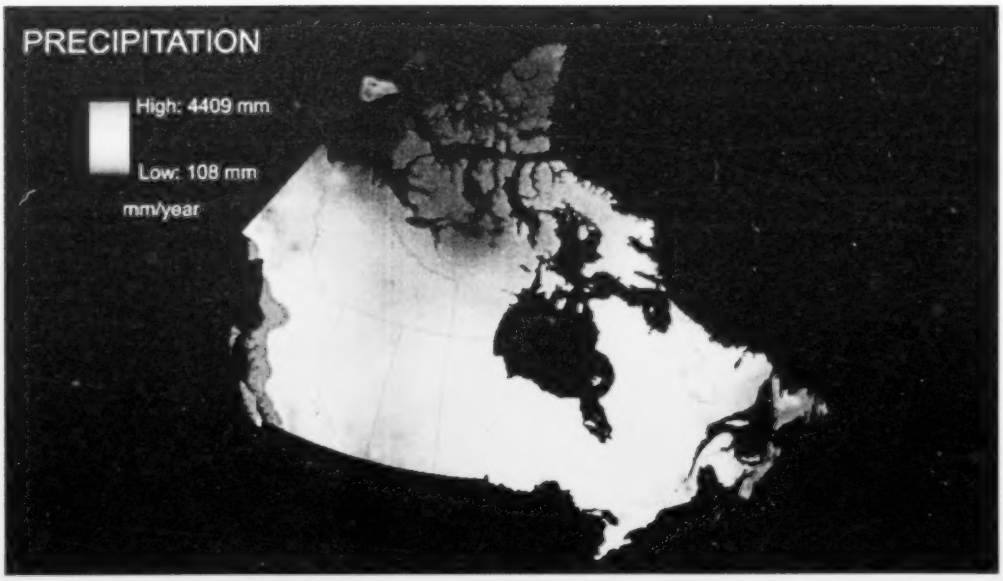
- create a national permanent mechanism (e.g. National Advisory Council) to foster and advocate groundwater in Canada, and to foster groundwater research focused on issues of provincial and national interest related to water quality and quantity, and including mechanisms for interjurisdictional co-ordination and public awareness;
- create opportunities for collaboration and discussion with stakeholders, similar to the Second National Workshop on Groundwater;
- create a nationwide network of experts and agencies to support implementation of the Framework;
- promote groundwater studies in other national initiatives or strategies; and
- produce a national newsletter and/or Web site as a forum where groundwater issues can be identified and discussed.

The middle-term actions (next 3 years) are to:

- fully develop a Canadian co-ordination mechanism (e.g. National Advisory Council) to support continuation of groundwater programs and secure funding for these programs;
- develop and implement a communications plan for programs;
- design and implement a national groundwater-monitoring system, consisting of a 'network of networks';
- develop, promote, and co-ordinate guidelines (e.g. for monitoring, aquifer-classification maps, and aquifer-vulnerability areas, and to support best-management practices);
- initiate a public-awareness program for groundwater;
- organize national workshops in conjunction with other events (e.g. International Association of Hydrogeologists, Geological Association of Canada–Mineralogical Association of Canada joint annual meeting) to present and discuss groundwater issues every two years; and
- identify criteria for groundwater research focused on issues of provincial and national interest related to water quality and quantity, obtain financial resources, and identify expertise to undertake the research.

The long-term actions (next 10 years) are to:

- characterize and inventory, within 10 years, the groundwater resource in settled areas of Canada, in terms of its quantity, quality, vulnerability, and sustainability; areas selected would depend on jurisdictional priorities;
- provide this knowledge to agencies, in all levels of government, responsible for management of the groundwater resource, in a format that is immediately useful to them;
- produce a national quantitative synthesis of Canadian groundwater resources;
- create a modern, distributed, interoperable groundwater information-dissemination network that can be easily accessed by the public and a wide range of users;
- refine criteria for groundwater-research requirements, where necessary, to focus on issues of provincial and national interest related to water quality and quantity, obtain financial resources, and identify expertise to undertake the research; and
- evaluate activities and targets on an annual basis.



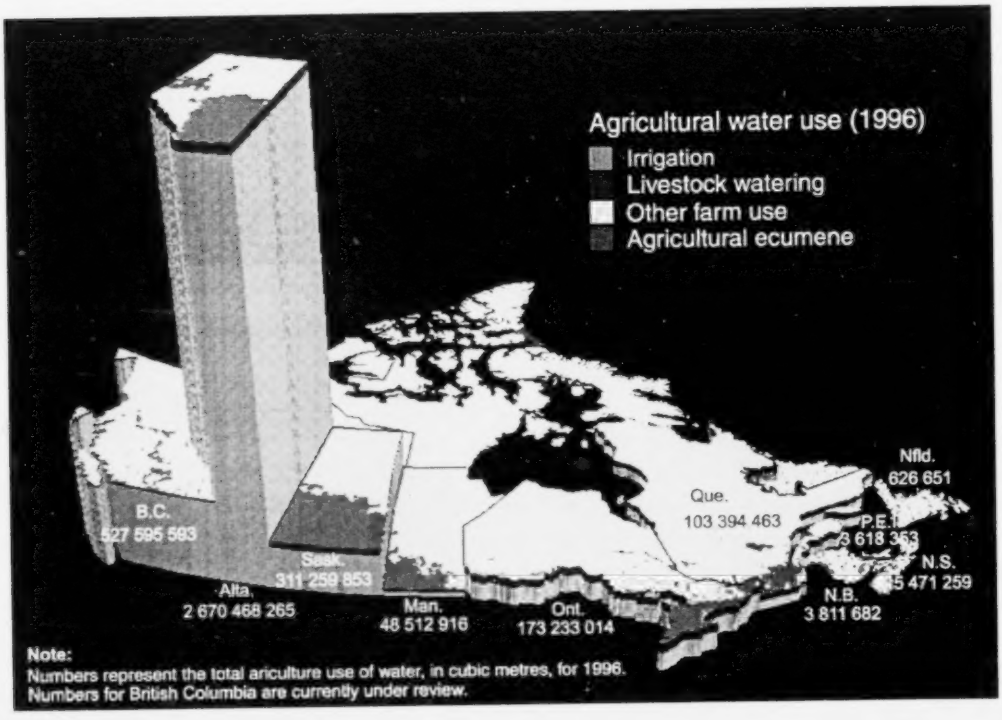
4.1 Potential outcomes

A number of potential outcomes for the Framework have been identified, including:

- improved understanding and scientific knowledge of groundwater resources;
- increased public awareness of the importance of groundwater resources;
- improved funding levels for necessary groundwater research, studies, and inventory;
- better guidance provided for groundwater-research needs and activities;
- more attention given to identifying and addressing common groundwater issues;
- increased opportunities for collaborative studies and research on common problems;
- development of innovative solutions to groundwater problems;
- effective co-ordination and collaboration of governments and agencies involved in groundwater management and protection;
- more opportunities to pool resources and knowledge, to reduce costs and duplication of efforts;
- improved communications and sharing of groundwater information among agencies and with the public;
- enhanced opportunities to access new technologies and expertise; and
- stimulated economic interest and investment in groundwater-related activities.

5 PREVIOUS INITIATIVES TOWARD NATIONAL GROUNDWATER PROGRAMS IN CANADA

A comprehensive review of all previous initiatives aimed at national groundwater programs in Canada is beyond the scope of this document. Several of these initiatives are briefly reviewed in this section, however, because of their relevance and potential linkages with the Framework described in this document.



5.1 Gilliland report (1990)

In 1990, a document entitled *Background on a Canadian Groundwater Strategy* was written by John Gilliland of Environment Canada. With time, the document came to be known as the 'Gilliland report'. In a letter dated September 24, 1992, he stated that "in order to get the ball rolling in developing a 'National' or 'Canadian' (or other) Groundwater Strategy, I have rewritten the DOE [federal Department of Environment] Strategy to make it more generally relevant to everyone's concerns, and not so specifically oriented towards DOE."

The Gilliland report contained 14 conclusions and 14 recommendations. The conclusions were focused under the general themes of:

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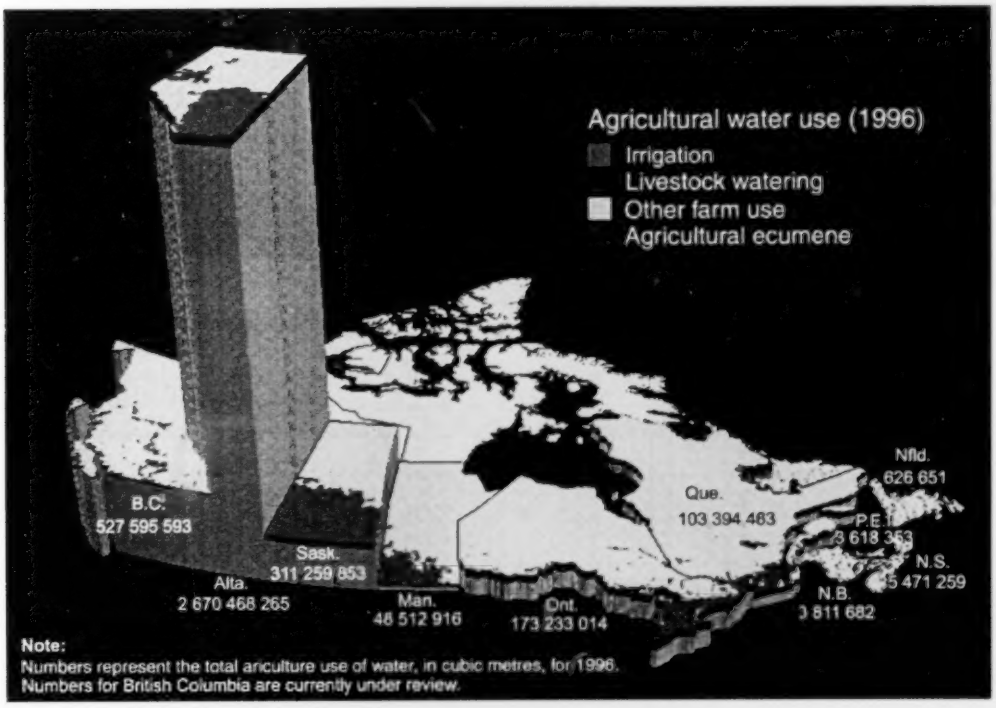

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The Gilliland report contained 14 conclusions and 14 recommendations. The conclusions were focused under the general themes of:

- need for new approaches;
- co-ordination of federal and provincial groundwater activities;

- development of guidelines for groundwater management;
- technical capability for groundwater contamination clean-up and prevention, and development of groundwater resources;
- government's access to state-of-the-art hydrogeological knowledge and expertise;
- groundwater databases;
- value of Canada's groundwater resources;
- value of other resources at risk from contaminated groundwater;
- present and future demands for groundwater;
- socio-economic research on groundwater issues; and
- public information and education on groundwater management, protection, and development.

In his comprehensive report, Gilliland analyzed in detail the roles of various 'actors': the federal departments, the provinces and municipalities, the industry, the universities, and the nongovernment organizations.

The Gilliland report, however, did not recommend a framework to further develop and implement his recommendations co-operatively and with an operation plan.

5.2 Canadian Geoscience Council study (1993)

In 1993, the Canadian Geoscience Council (CGC) created a task force on groundwater resources research. That group produced a document entitled *Groundwater Issues and Research in Canada* (Morgan, 1993).

The CGC Task Force on Groundwater Resources Research reported that:

- groundwater issues have historically received little attention from the federal government and most provincial governments, in either an environmental or a human-health context;
- the ability of government and industry in Canada to manage and protect groundwater resources is limited by deficiencies in information on many aspects of the resource, and Canada needs to make major advances in areas such as groundwater inventory, protection, and research, to achieve responsible and effective management of the resource;
- groundwater research in Canada experienced large growth from 1983 to 1993; and
- a lack of research projects in which M.Sc. and Ph.D. students could participate has been a limiting factor in the production of groundwater specialists in Canada.

The task force made several recommendations, directed at the federal government, to improve groundwater management and protection in Canada. Some of these recommendations were addressed by different federal departments (e.g. Environment Canada and Natural Resources Canada). The report will soon be 10 years old, and there have been many changes since 10 years ago. In 1993, for example, there were only four or five universities in Canada with an active hydrogeology program. Now almost every university in Canada has hydrogeology professors and a groundwater research program. Also, remediation and dense nonaqueous phase liquids (DNAPLs) were the major issues back then; the focus now is on sustainability and groundwater protection. A thorough review of the current status of this document falls beyond the scope of this Framework. Those interested in a review of the 1993 document can read the Blundell report, produced at the request of the commission of the Walkerton inquiry (Blundell, 2001).

An important difference between the CGC document of 1993 and the current Canadian Framework for Collaboration on Groundwater is that the main recommendation of the former was for a strong role for the federal government, whereas the latter is based on a co-operative effort with national consultations and intergovernmental partnerships. An important similarity, on the other hand, is the strong recommendation to complete an inventory of the nation's groundwater resources.

5.3 Federal Water Policy (1987)

In 1987, the Federal Water Policy (Environment Canada, 1987) provided the general directions for the federal government's groundwater programs. That policy expressed an explicit federal commitment "to the preservation and enhancement of the ground water resources for the beneficial use of present and future generations." That policy clearly stated that the federal government will develop, with provincial governments and other interested parties, appropriate strategies, national guidelines, and activities for groundwater assessment and protection.

5.4 Karvinen and McAllister report (1994)

Karvinen and McAllister (1994) identified emerging groundwater policy trends in Canada that continue to be relevant today. They cited lack of interjurisdictional co-ordination between levels of government and between local governments, lack of public and political awareness, and lack of an adequate mandate and funding to properly document the quality and quantity of groundwater as being the main barriers that inhibit effective groundwater management.

5.5 Other reports

Several other important reports, although not Canadian groundwater initiatives, do discuss, at a national level, Canada's groundwater resources, their usage, or gaps in our knowledge. Fisheries and Environment Canada (1978a, b) produced two maps of Canada showing the location of major surficial and bedrock aquifers, expected yields (L/s), and quality of the groundwater. Brown (1970) produced a report describing groundwater conditions in the major geological regions across the country. A report by Hess (1986) was a very comprehensive summary of groundwater use in Canada in 1981, and twenty years later it is still widely cited because the statistics presented then have not been updated. In another relevant report, Jackson (1987) presented an overview of the state of groundwater research in Canada during the late 1980s, focusing on the major field studies that were being undertaken to understand the transport and fate of contaminants in the subsurface. A series of comprehensive provincial groundwater reports were produced jointly by Environment Canada and provincial environment departments and geological surveys (Pupp et al., 1989, 1990, 1991; Grenier, 1989; MacRitchie et al., 1994; Betcher et al., 1995). These reports discussed the physical and natural quality characteristics of the aquifers, groundwater usage and issues, quantity and quality concerns, ground water legislation, and groundwater programs. Finally, in 2000, the International Joint Commission (2000) called on all governments to enhance groundwater research in the Great Lakes basin.

6 CO-ORDINATION AND COLLABORATION MECHANISM

Defining a mechanism for co-ordination (understood here as a common framework for conducting groundwater activities at the national scale) is a major challenge. Analysis of the respective roles of the provincial and federal governments falls beyond the scope of this document; instead, the proposed co-ordination is based on two underlying principles:

- The provinces have the major legislative-constitutional responsibility for water, including groundwater.
- The federal government has a significant regulatory responsibility over a number of groundwater issues, such as transboundary water issues, the Canadian Environmental Protection Act, and the Canadian Drinking Water Guidelines.

Recent events, such as the Walkerton accident, have put groundwater into the media, thereby raising public awareness of this very precious resource. Clearly, as the Federal Water Inquiry stated in 1985 (Pearse et al., 1985), the public is not interested in what level of government does what; the public simply wants effective action. The events in Walkerton focused public concern on the safety and security of water supplies, and raised questions regarding roles and responsibilities.

In the January 2001 Speech from the Throne (Government of Canada, 2001), the federal government noted Canada's responsibility, as the steward of one of the world's largest supplies of fresh water, to protect this critical resource. The Speech from the Throne stated that "Safeguarding our water is a shared task among governments, industry, and individual Canadians. The Government of Canada will fulfil its direct responsibilities for water, including the safety of water supplies on reserves and federal lands." Thus, we are all responsible and we all have roles. The Speech from the Throne also stated that the federal government will:

- develop stronger national guidelines for water quality;
- fund improvements to municipal water and wastewater systems through the federal-provincial-municipal Infrastructure Canada program; and
- invest in research and development, and advanced information systems, to enable better land use and protect surface water and groundwater supplies from the impact of industrial and agricultural operations.

The approach suggested here is based on the acknowledgment of the strong and diverse hydrogeological capabilities that exist within each province, and is intended to serve as a mechanism to foster collaboration and multifaceted support for existing and future provincial initiatives. It is also designed to ensure that groundwater issues of national importance are not only addressed appropriately on a scientific basis, but also that the importance of the long-term protection and management of the resource becomes a significant concern for all levels of government.

Indeed, because of the complexities of constitutional authority, the federal government working in partnership with the provinces, territories, and First Nations will be a key component in the formulation of any comprehensive framework for co-operation and collaboration in the vital matter of addressing the looming groundwater-resources issues in Canada.

6.1 Mechanisms for co-ordination, stewardship, and partnerships

Various mechanisms for implementing the Canadian Framework for Collaboration on Groundwater were considered. The preferred mechanism would be centred on a ***Canadian Groundwater Advisory Council*** (CGAC), which would provide advice to ***a Federal-Provincial Groundwater Committee*** (FPGC). This executive committee could be supported by federal departments on the one hand, and provincial agencies on the other. Both could provide guidance and funds; major funding could come, for example, from a 'pool' composed of various federal departments. Two working groups, one for policy and one for science, could support the CGAC and the FPGC, and could link to other national networks or initiatives, such as the Canadian Water Research Network (CWRN), the Canadian Council of Ministers of Environment (CCME), and the Canadian Water Network (CWN). A series of national programs would be defined and managed by the CGAC (*see* chapter 7). A national groundwater office would provide administrative support to the FPGC.

Because it is a truly national co-operative endeavour, this council should not be led by a federal department alone. Rather, a combination of federal departments, provincial agencies, and other stakeholders could form the council and develop the activities needed. The recommended structure for the council is presented in Appendix 3.

Following the discussions on this Framework at the Second National Workshop on Groundwater in September 2001 (*see* section 2.2), the main activities that will be covered by this co-operative framework are consultation, co-ordination, education, synthesis, mapping, assessment, research, and special expertise. Activities that will not be covered are regulation, resource management, and international issues.

6.2 Canadian Groundwater Advisory Council (CGAC)

One of the greatest challenges for the Canadian Groundwater Advisory Council (CGAC) is defining its scope. The scope of CGAC must be defined in terms of priority areas, research programs, regional and national scales, time frame, and responsibilities. For the CGAC to be successful, the roles of governments, nongovernment groups, industry, and universities must be specified within a national framework. Strong government participation is critical to its success. A strong, long-term government commitment is necessary in order to build capacity in groundwater activities at the regional and national scales. The main roles of the CGAC would be to advise, co-ordinate, and manage.

Suggested representation on the council would be as follows (the numbers indicated are the current estimation and may change over time):

Jurisdiction	Persons
Provincial governments (one representative from each province)	10
Yukon Territory	1
Federal government (Natural Resources Canada, Environment Canada, Agriculture and Agri-Food Canada)	3
Academic	3
Stakeholders (e.g. Canadian Council of Ministers of Environment, Canadian Water Network, Canadian Ground Water Association)	5
Industry (consultants)	1
Federation of Canadian Municipalities	1
Total membership	24

The CGAC could serve as groundwater advisors (and supporters) to stakeholder organizations. Other potential stakeholders are those with a major dependence on groundwater, such as municipalities, farmers, or consultants (e.g. a national farm organization, a municipalities association, and a representative of the groundwater consultants).

6.3 Partnerships

All CGAC partners would be encouraged to participate in the development of the Canadian Framework for Collaboration on Groundwater and associated national programs. Each partner would be able to influence the goals and priorities of the Framework, through its representatives to the national council and executive committee.

When this document was prepared, the work of the National Ad Hoc Committee was still in progress and the list of partnerships has not yet been finalized. The potential partners that have already shown interest in participating in the CGAC are:

British Columbia Ministry of Water, Land and Air Protection
Saskatchewan Water Corporation
Saskatchewan Research Council
Ontario Geological Survey
New Brunswick Department of Environment and Local Government
Canadian Ground Water Association
University of Waterloo
Natural Resources Canada
Environment Canada
Agriculture and Agri-Food Canada
Health Canada
Prairie Farm Rehabilitation Administration
Alberta Energy and Utilities Board

6.4 Federal-Provincial Groundwater Committee (FPGC)

The Federal-Provincial Groundwater Committee (FPGC) would seek the timely advice of the Canadian Groundwater Advisory Council. The initial FPGC would consist of a maximum of 13 people, with a representative from each provincial government, the Yukon Territory, Natural Resources Canada, and Environment Canada. This committee would steer the CGAC and the Canadian Framework for Collaboration on Groundwater. It should be responsible for the implementation of the Framework, for monitoring progress, and for regular reporting of results.

The FPGC would have strong links to government via the Canadian Council of Ministers of Environment (CCME), whose mandate and direct input to policies would support and give credibility to the CGAC. The FPGC would also have an important link via the National Geological Surveys Committee (NGSC), as suggested during the Second National Workshop on Groundwater. The Intergovernmental Geoscience Accord of the NGSC, signed in 1996 by ministers responsible for geological survey organi zations, could be the official vehicle to manage and disseminate groundwater knowledge that will be produced by the CGAC.

The FPGC would operate under the terms of reference agreed upon by the initial members. Membership would be by official invitation to persons with a strong scientific background, managers, or scientists with strong links to senior management and government politics. Persons sitting on this executive committee should be high-ranking officers who do not necessarily deal with policy but have input to policy (i.e. officials who can provide briefing material to the minister of their jurisdiction).

6.5 CGAC secretarial support

The Canadian Groundwater Advisory Council would be operated by a permanent program office of two or three full-time staff. Its functions would be to support the CGAC in consultation with the FPGC, establish an effective communications plan (including a Web site), publish the work of the data-model teams, and seek out and administer funding to build CGAC. The office, which would be sustained by Natural Resources Canada, should be in place by April 2004.

6.6 Working groups

A series of working groups could be established by the CGAC, as required, to deal with various aspects of the Framework, such as policy, science, or groups by scientific discipline (e.g. standards, communications).

7 NATIONAL CO-OPERATIVE PROGRAMS

This chapter describes an approach to addressing groundwater issues in Canada through a series of national co-operative programs. National co-operative programs are required because there are many similar and common groundwater issues and problems facing Canadians in various parts of the country. In addition, Canada has considerable valuable expertise that needs to be identified and accessible in order to provide the resources through which the country's groundwater problems can be addressed. It is recognized that the main issues of importance tend to be specific to conditions within each province and are significantly influenced by provincial mandates. Therefore, a national co-operative groundwater initiative can be defined as a program that will:

- a ssist all levels of government in making informed decisions regarding the protection, management, and sustainability of Canada's groundwater resources;
- benefit Canadians who use groundwater;
- be applicable to all regions of Canada;
- be integrated with the applicable municipal, provincial, territorial, and federal groundwater mandates and activities; and
- facilitate a funding mechanism, through a collaborative approach, to support projects of mutual interest.

There are currently many groundwater issues in Canada that require immediate attention. Some of the most critical are outlined in this chapter. Although some can be addressed with our current level of technical understanding, others will require additional knowledge and training. The overall structure of the national co-operative programs can be categorized into four main areas:

1) **Applications of existing expertise and technology:** programs that can be undertaken with our current level of scientific and technical knowledge

2) **Issues requiring additional scientific research:** research to provide the knowledge to address problems for which the current level of scientific and technical knowledge is insufficient

3) **Training:** providing current scientific, technical, and regulatory knowledge to those working with groundwater issues

4) **Public awareness:** providing groundwater information, and access to this information, to decision-makers and the public

From a scientific and technical viewpoint, implementing some of the proposed national co-operative programs will not be difficult, because Canada currently has the required information and expertise. Implementing some of the most critical programs, however, will require much more than scientific and technical expertise. It will require regional and local co-operation at a scale that may force a fundamental paradigm shift in the approach to the study of Canada's groundwater. At the same time, national co-operative programs can only be implemented if they fall within current federal and provincial mandates, focus on province-specific issues, and involve communication and co-operation among all stakeholders. And finally, it must be recognized that, because Canada's groundwater issues and priorities change, the national co-operative programs must be flexible enough to recognize and adapt to these changes.

The following sections present a summary of proposed national groundwater co-operative programs. These programs fall within the four groups listed above: application of existing knowledge (a national groundwater inventory, groundwater-monitoring programs), scientific research, public awareness, and training.

7.1 Applications of existing expertise and technology

7.1.1 National inventory of groundwater resources and program of regional groundwater assessments

During the last few years, there have been many concerns in Canada about the country's groundwater resources, involving questions about the future sustainability of those resources. It is recognized that groundwater and surface water are integrally linked through the hydrological cycle, and that the sustainability of groundwater resources is a function of many factors, including depletion of groundwater storage, groundwater–surface water interaction, reduction in streamflow, loss of wetland and riparian ecosystems, saltwater intrusion, and changes in groundwater quality. Each groundwater system and development situation is unique and requires an analysis adjusted to the nature of the existing water issues. Two collaborative programs that would address the question of sustainability are a national inventory of groundwater resources and a national program of regional aquifer assessments.

A national inventory of Canada's groundwater resources is needed for Canada's federal, provincial, and municipal governments to 1) plan, promote, and regulate population growth, agricultural activities, and industrial development; 2) adapt to climate change; and 3) implement environmental conservation and protection programs. Planning, promotion, and regulation require accessible, local knowledge of groundwater quantity, its chemical quality, and its vulnerability to sources of contamination. Such knowledge would reside in a **National Groundwater Inventory**.

A National Groundwater Inventory (herein after called 'the Inventory') would serve four purposes:

1) Where groundwater reserves of acceptable quantity and quality are underutilized, governments could use a National Groundwater Inventory to identify and promote opportunities for water-intensive industrial development and population growth, or waste disposal. Where the groundwater quantity, quality, or waste-assimilation capacity is overutilized, governments could use the Inventory to assist in managing growth and development.

2) For water-intensive industries that are mobile (e.g. food processors, feedlots), the Inventory would identify regions suitable for industrial expansion. For less mobile, water-intensive industries (e.g. oil-sands plants), the Inventory would help industry identify, and plan for, water-related limits to growth.

3) The Inventory would help water-intensive industries and population centres identify contingency or 'standby' groundwater reserves. Identification of contingency groundwater reserves would help buffer Canada's water-intensive industrial base and population centres from anticipated climatic variations accompanying global warming. The Inventory would also help industry and others identify opportunities for energy conservation through use of low-gradient geothermal heating and cooling technology.

4) The Inventory would provide baseline information on groundwater quantity and chemical quality. From this baseline information, future generations could detect and track long-term changes in aquifer replenishment or chemical quality, and then take the appropriate mitigation, protection, or conservation measures.

A standardized workflow to build the Inventory would actually follow a pattern typical of most groundwater-resource characterization studies. The general steps could be as follows:

1) The geometry of the aquifers of the target area is mapped systematically, first at a regional scale and thereafter 'zooming' to larger scales according to need. Aquitards should be mapped systematically as well. For some areas of Canada, the geological framework is sufficiently advanced to proceed immediately with a groundwater-resource inventory. But, in other areas, the framework is either not in place at the required scale or requires updating. Because of the advanced degree of subsurface geological interpretation required, this activity should be performed by, or in close co-operation with, geological surveys in each jurisdiction.

2) Representative ranges of the physical and hydraulic properties of each aquifer are tabulated. These properties can be derived from cores, aquifer tests, downhole instruments, outcrop analogues, etc.

3) The distributions of hydraulic head are mapped from pressure or water-level data. In sloping aquifers with groundwater of variable density, maps of flow vectors may be needed to understand flow directions.

4) Natural variations in chemical quality are mapped. Natural variations in isotopic composition should be considered, as well as those of major and minor dissolved constituents.

5) The locations and degrees of groundwater coupling(s) to surface-water bodies and recharge areas are mapped and described.

6) From maps of hydraulic head, groundwater chemistry, and surface hydrology, the groundwater-flow systems are charted in terms of geometry and relative place in the hierarchy of natural flow systems. Flow-system charts placed in the Inventory would be available to future contributors, thereby reducing costs and maintaining consistency over time. Flow-system water balances should be quantified at this step.

7) The aquifer bodies (or parts thereof, in the case of areally extensive aquifers) are assigned to the hosting flow system(s).

8) Volumetric methods are used to assign groundwater reserves in elastic storage in the aquifers.

9) Natural, steady-state flux of groundwater flowing through the aquifer, delivered by the host flow system, is quantified and expressed in terms relevant to the water balance of the host flow system.

10) From consideration of the flow-system geometry, the linkage between aquifers, the geometry and strength of aquitards, and the nature of couplings to surface-water bodies, each aquifer is categorized as renewable or nonrenewable on the time scale of human development, and groundwater reserves are assigned accordingly. Estimates of aquifer sustainable yield can also be derived according to a standardized definition, if desired.

The keys to building a National Groundwater Inventory from these steps are 1) the combined work of a multitude of municipal, provincial, and federal agencies; 2) consistency, standardization, and completeness; and 3) either centralized digital storage or easy, universal access to inventory data across a distributed network. The Inventory would require updates as groundwater systems change over time. Updates can be made annually or as each jurisdiction sees fit. Estimated or potential reserves on record in the Inventory may decrease due to groundwater production or negative changes in surface-water replenishment. Reserves may increase due to natural replenishment, artificial recharge or injection, or remapping of aquifers.

A National Groundwater Inventory does not have to be a stand-alone project. Rather, it could be built by provincial and national agencies in the course of discharging their regular obligations through the adoption of a standardized workflow. The standardized workflow would be designed to generate the data for the Inventory as a byproduct of regular government activities. This would ensure that the Inventory starts in the priority areas of each jurisdiction in Canada and thereafter builds out to the peripheries. It would also ensure that the incremental cost of building the Inventory is minimized, although there will be some costs incurred by the national agency or body charged with co-ordinating contributions and maintaining the requisite digital infrastructure. The CGAC could play a role in co-ordinating development of the digital infrastructure that houses the actual inventory. Industry and consultants adopting the standardized workflow would also be able to contribute to the Inventory.

A collaborative series of regional aquifer assessments is proposed to complement the Inventory. Regional-scale studies provide the context for understanding changes in the Inventory and for predicting future impacts of development and climate change. Regional studies could benefit, on the one hand, from data, knowledge, databases, and infrastructure from existing projects and, on the other hand, from existing expertise and applicability. As well, process-focused local studies could be targeted to specific hydrogeological settings. A regional approach to process-based science would expand the applicability of these investigations across hydrogeological settings.

The CGAC could play an important role in co-ordinating and implementing a National Groundwater Inventory. The CGAC could also co-ordinate regional assessments by bringing together those individuals in the various levels of government, universities, and the private sector who have existing information and data pertaining to the target area, considerable expertise in undertaking these assessments, and local knowledge of the hydrogeological regime. The CGAC could also ensure that successful strategies, techniques, and tools used in other regional groundwater assessments will be available to all parts of the nation. With respect to a National Groundwater Inventory, CGAC could act as the repository for Canada's regional groundwater assessments, ensuring that information relating to each groundwater assessment is publicly available. The CGAC could also act as a clearinghouse for tools, techniques, and expertise for future regional groundwater assessments.

Priority areas for regional-scale studies could be proposed and designed by the CGAC. Each study could form a regional framework for building the Inventory or for future collaborative work. Execution of priority regional studies could be managed or co-ordinated by CGAC working groups or subcommittees. The working group or subcommittee for each framework would consist of provincial-federal representatives having a common secretariat or program office (*see* Appendix 3). The terms of reference for the operation, membership, and financial responsibilities of each framework will be outlined in subsequent documents by the CGAC.

Local-scale resource inventories and groundwater assessments have been undertaken by a variety of provincial and federal agencies. Thus, a wealth of existing knowledge is available for designing strategies for both undertaking regional groundwater studies and implementing groundwater-resource inventories. One example of a practical and successful inventory is the Alberta Energy and Utilities Board's inventory of Alberta's oil and gas reserves. Two examples of successful, collaborative, regional aquifer assessments are the Geological Survey of Canada's Oak Ridges Moraine project in Ontario and the assessment of the Carboniferous Basin as part of the Maritime Groundwater Initiative. The latter is an excellent example of collaboration among various federal and provincial agencies, universities, and the private sector to maximize the benefits of regional groundwater expertise. More details on each are found in Annexes 1 and 2 to this chapter (sections 7.5 and 7.6).

7.1.2 Monitoring Canada's groundwater

Canada's groundwater resources are threatened by a variety of natural and anthropogenic activities. Natural threats, such as natural contaminants (metals, salts, and gases) and climate change are typically very widespread and their impact is long term. Human activities, such as overpumping, contamination from spills, resource development, and industrial and agricultural activities, are generally localized and their impact occurs relatively quickly. Once groundwater quality and quantity is adversely impacted, there will be a detrimental impact on surface waters (rivers, lakes, wetlands), rural development, and agricultural activities.

Groundwater-monitoring programs offer a means of recognizing changes to natural groundwater conditions due to natural and anthropogenic activities. Groundwater-monitoring programs are essentially early-warning systems, which will enable us to act in a responsible and timely manner to manage and protect Canada's groundwater resources. Groundwater-monitoring programs can be grouped into two general categories:

- Those that address specific and localized problems
- Those that support long-term and regional ground water-resource assessments

Monitoring programs that address specific and localized problems or issues are typically very localized within the vicinity of the problem, and monitoring is relatively short term, being undertaken only for the duration of the problem. Typical examples are monitoring of groundwater contamination due to a spill of industrial solvents, a leaking gasoline-storage tank, drawdown due to a municipal well, etc. These issues (and accompanying monitoring-well networks) are typically handled at a municipal or provincial level, and would not be the focus of the monitoring efforts of the CGAC.

Monitoring programs are also required to support regional groundwater-resource assessments. An example of the value of a monitoring-well network would be to assess the impact of urbanization and increased groundwater extraction on groundwater quality, recharge, and water levels. These programs require long-term monitoring and therefore long-term commitments to maintain the monitoring wells and data collection. The primary roles of these monitoring programs are to:

- monitor ambient groundwater quality and water levels on a regional scale;

- assist in the management of groundwater during periods of problems;
- assist in the protection of sensitive and important areas of groundwater recharge;
- assess the impact of development and land-use activities on groundwater resources; and
- distinguish between short-term and transient natural fluctuations (e.g. seasonal) and long-term impacts due to anthropogenic activities.

Monitoring groundwater resources on a regional scale requires more than studying groundwater levels and quality via shallow and deep wells. It must be recognized that groundwater conditions on a regional scale are fully integrated within the overall hydrological cycle, so monitoring must take an integrated approach in which all hydrological components affecting, and affected by, groundwater are monitored. This would also include tracking major groundwater and surface-water removal. Thus, groundwater monitoring in support of regional groundwater assessments must be combined with surface-water (lakes, rivers, wetlands) and meteorological (precipitation, temperature) monitoring. Although the Water Survey of Canada and the Meteorological Service of Canada operate extensive monitoring networks across Canada, additional monitoring stations may be required. A database of hydrometric data collected by Environment Canada and provincial, municipal, and private agencies is already available electronically (http://www.msc-smc.ec.gc.ca/wsc/products/hydat/main_e.cfm?cname=hydat_e.cfm). In addition, monitoring programs require more that just the accumulation of data. They must include tools to interpret the data, such as numerical models, GIS, and uncertainty analysis. Monitoring programs must also involve timely access to information, either during its collection (i.e. satellite transmission of data from the monitoring location to the archival site) or its distribution (i.e. Web-based storage of data). There is also a need to recognize that the monitoring programs must be continually assessed, especially during the early years of their existence. It is possible that wells were incorrectly located on the basis of limited information and must be relocated, and that quantity and quality parameters being monitoring may no longer be the most relevant.

It is envisioned that the proposed regional groundwater-monitoring programs would not be a national groundwater-monitoring program (i.e. not managed by the federal government). Control of, and responsibility for, groundwater monitoring and groundwater-monitoring networks would be under the jurisdiction of each province. Individual provinces, regions, and municipalities are in the best position to determine the number and location of monitoring wells, and to select parameters to be monitored. In fact, most provinces and several regions currently operate, or are expanding, extensive groundwater-monitoring networks to suit their own specific needs. Rather, it is proposed that CGAC could play a role in the development of groundwater-monitoring programs in support of the regional groundwater assessments by:

1) facilitating a linking of existing federal, provincial, municipal, and industrial groundwater-monitoring networks (e.g. a Web-based network of existing monitoring networks);
2) acting as a clearing house for information on how to design, construct, and operate monitoring networks;
3) stressing that all monitoring programs have an accompanying quality assurance-quality control (QA-QC) program (e.g. manual measurements to check for transducer drift, plus regular transducer maintenance and calibration);
4) ensuring that the responsible agencies maintain a long-term commitment to operation and maintenance; and
5) preparing guidance documents describing methods for locating monitoring wells, constructing monitoring wells, and operating monitoring-well networks.

Groundwater-monitoring programs have existed in most provinces, but for many reasons these have been neither exhaustive nor consistent. Furthermore, the data collected have not necessarily been available in electronic databases, nor have they been thoroughly used to fully assess groundwater as a resource. Motivated by recent groundwater-contamination issues, many provinces are re-establishing monitoring-well networks, adding new wells to existing networks, and re-evaluating well locations and parameters monitored (*see* Appendix 1).

Motivated by this Framework and the work of the National Ad Hoc Committee, compilation of data and inventorying of the existing groundwater-monitoring networks have already begun in some provinces. The Saskatchewan Research Council has very recently begun compiling information on networks from the provinces of British Columbia, Alberta, Saskatchewan, and Manitoba, and data from Quebec will soon be available. This initiative, for example, could be the beginning of a much broader program across Canada.

7.2 Issues requiring additional scientific research

Canada has a strong tradition in undertaking groundwater research, and an international reputation for the scope and quality of groundwater research that developed from the initial studies undertaken in western Canada during the 1950s and 1960s. Currently, research expertise resides within several universities, federal research institutes, provincial agencies, and private industry. Nevertheless, it is recognized throughout Canada that a variety of problems and issues related to the protection and management of our groundwater resources cannot be adequately addressed with our current scientific knowledge. This may be, in part, due to the lack of resources required to study current issues, but it is more likely due simply to the fact that research priorities and issues change over time. For example, various past priority issues, identified in previous national groundwater studies (e.g. Jackson, 1987; Gilliland, 1990; Morgan, 1993; *see* chapter 5), have been addressed as research resources have been directed toward these issues (e.g. impact of mining on groundwater, role of groundwater in hydrology of wetlands). Also, new issues that could not have been foreseen even a few years ago are only now coming to light (e.g. contamination of groundwater by pathogens and natural arsenic). Thus, because research needs will change over time, the CGAC would have to be flexible in its approach to dealing with evolving issues.

One of the fundamental roles the CGAC could play is the facilitation of access to appropriate scientific expertise within universities, federal and provincial research agencies, and the private sector. This may be in the form of current literature, research personnel, technology, and/or consulting expertise that is available throughout Canada and, in some cases, internationally. The CGAC would function as a reference contact point or 'clearing house' of technical support that can be accessed by anyone interested in groundwater management.

It is clearly recognized that groundwater problems and issues vary provincially and regionally across Canada. Examples of major threats to the groundwater resources of the provinces, as well as other issues, are listed in Appendix 1. Although there are many issues of interest at provincial or regional scales (e.g. soil salinization, oil-sands tailings management), there are numerous issues that are of national concern (e.g. pathogens in wells, estimating rates of recharge, impact of climate change, bulk water sales). The CGAC would provide advice and direction on current research areas that focus primarily

on national issues related to the best protection and management of groundwater resources. Defining priority groundwater research topics would involve input from scientists, policy- and decision-makers (provincial and federal), and stakeholders. Some of these research areas are tabulated in the following subsection.

7.2.1 Priority areas for current research

The following is a list of current groundwater issues that cannot be addressed due to insufficient scientific knowledge. This list is not presented in any order of priority but is intended to include the technical issues that are the most significant relative to the long-term protection and management of Canada's groundwater resources. These were derived primarily from the results of the First and Second National Groundwater Workshops facilitated by the Geological Survey of Canada (GSC) in June 2000 and September 2001:

- Groundwater flow in fractured rock environments
- Evaluating and modelling surface water–groundwater interaction
- Integrated (groundwater–surface water–meteorological) approach to modelling and managing groundwater at a watershed scale
- Naturally occurring groundwater constituents that pose a risk to human health
- Techniques and tools to measure recharge at various scales
- Role of aquitards in regional groundwater assessment
- Geophysics and geostatistics as tools to estimate physical parameters at appropriate scales
- Bulk exploitation and/or export of groundwater (domestically and internationally)
- Potential impacts of climate change on groundwater resources

A primary role of the CGAC would be to foster an environment that can assist province-specific research to be addressed, through the contribution of expertise, access to appropriate data and information, and, if possible, facilitation of funding possibilities. The priority research areas will continually evolve as the knowledge base and understanding of the groundwater resource expand.

7.3 Improved access to groundwater data and information

A considerable amount of groundwater data and information exist within Canada's municipal, provincial, and federal government agencies, universities, and the private sector. Although the data and information are invaluable when informed decisions are required, most are not readily available or are not commonly known to exist. Here, the term 'data' refers to measured values, such as water levels, chemical analyses, hydraulic conductivities, or well locations, that have not been interpreted within a specific context. The term 'information' refers to the interpretation of data within a specific context and with specific hydrogeological knowledge, such as relating water-table fluctuations to seasonal conditions and pumping levels.

It is important that each stakeholder has access to the right type of data or information. For example, groundwater professionals and scientists need reliable data to make informed interpretations about the state of groundwater or threats to groundwater in a particular area. Policy-makers and the public need reliable information to make accurate decisions about the protection and management of groundwater resources. It is also important that each stakeholder has controlled access to specific data or information, to ensure that it is not misinterpreted. For example, although the public are aware of groundwater issues and concerns and can

make good use of nontechnical groundwater information, they may not have the knowledge to interpret data or put it into the proper context (e.g. data on concentrations of arsenic or lead in drinking water without information on their relationship to Canadian Drinking Water Guidelines).

7.3.1 Comprehensive data and knowledge bases for groundwater professionals

An essential goal of this national program initiative would be to establish new, or link existing, databases and technical information in such a way as to be accessible to groundwater professionals and scientists throughout Canada. This would ensure that all stakeholders involved in the management of groundwater resources have convenient access to the most current information available, to support individual initiatives anywhere in Canada. The role of the CGAC in this regard would be to facilitate the interconnection of existing databases and the compilation of relevant groundwater knowledge and expertise in such a way as to ensure easy access by all stakeholders. The main steps in the process would be as follows:

1) Construct an archive of existing groundwater databases, including
   - water-well records
   - groundwater-quality and water-level monitoring data
2) Identify relevant information systems
3) Construct an archive of existing groundwater knowledge, including
   - case studies
   - compendium of scientific and/or technical papers and reports
   - directory of groundwater specialists in Canada
4) Upgrade or transfer databases to new platforms as required
5) Facilitate the move to Internet access for databases and information
6) Establish links for GIS and computer-modelling applications

The CGAC could provide interested parties with advice and recommended protocols to ensure that the development of new databases follows a compatible format that can be easily linked with other existing databases. For example, CGAC could work directly within the existing Canadian Geoscience Knowledge Network of Natural Resources Canada to establish a functioning data- and information-management model for groundwater. The CGAC could also ensure that the data are accurately interpreted to provide information that would be used by policy-makers and the public.

7.3.2 Groundwater information for the public and policy makers

Increasing public awareness of groundwater resources and having up-to-date groundwater nontechnical information readily available to all parts of society are important elements for an effective groundwater framework. Ensuring that the public, educators, and decision-makers are well informed will enable these individuals to take a more proactive approach to protecting and sustaining groundwater supplies. There are a number of ways that public awareness and access to important information can be improved.

7.3.2.1 Establishing information sources

- Create and distribute fact sheets and information bulletins on groundwater topics
- Develop brochures and publications on various aspects of groundwater
- Create groundwater-information Internet sites and establish links to related sites
- Establish groundwater newsletters
- Increase use of existing groundwater news and information mailing lists that serve the Canadian hydrogeological community (e.g. the Canadian Hydrogeology [GWCAN-L] and Groundwater Modelling [GWM-L] mailing lists).

7.3.2.2 Education programs

- Promote groundwater in school programs and at relevant events (e.g. Earth Day)
- Support and augment existing water-education programs (e.g. Project Water Education for Teachers [WET], Groundwater Foundation)
- Teach about groundwater by targeting specific individuals, groups, and associations
- Develop a groundwater speakers' bureau (i.e. experts who are available to speak on various aspects of groundwater)
- Hold groundwater information and/or protection workshops in communities with various partners
- Seek out and engage potential sponsors for workshops (e.g. associations, businesses, local governments)

7.3.2.3 Community initiatives

- Assist with aquifer signage in communities dependent upon groundwater
- Assist aquifer protection societies in communities dependent on groundwater
- Assist groundwater stewardship projects with volunteer groups and/or associations

7.4 Training and accreditation programs

Many aspects of groundwater management, development, and protection are rapidly changing in response to recent advancements in knowledge, improved analytical capabilities, and new technologies. In addition, public expectations and higher standards will increase the need for trained, knowledgeable, and licensed/accredited persons to address Canada's groundwater issues. There is a need for a variety of training programs to ensure that those involved with Canada's groundwater resources have the knowledge to make informed and accurate decisions. There is also a need for accreditation to reasssure the public that those responsible for developing, managing, and protecting Canada's groundwater resources are competent. These programs will require input from industry, academia, and government. Four levels of training programs and accreditation are required:

1) Programs to produce groundwater professionals working in industry
2) Programs to produce groundwater scientists
3) Programs to produce groundwater technologists, including water-well drillers
4) Short courses to upgrade peoples' knowledge and skills with recent information

Groundwater professionals, including consulting hydrogeologists, groundwater engineers, and government regulatory personnel, are generally those who assess, develop, manage, and protect Canada's groundwater resources. Their primary products are reports to industry, municipalities, and the provincial and federal governments. They receive training through geology and engineering undergraduate and graduate programs at Canada's universities. Although the University of Waterloo offers Canada's most extensive groundwater program, almost all of Canada's universities offer smaller but excellent programs. These universities all offer essentially the same introductory undergraduate-level course in hydro geology. In contrast, universities do not offer the same graduate-level courses (e.g. focus on unsaturated zone, numerical modelling, DNAPLs, etc.) because the specialization of each university is a function of the area of expertise of the professor(s) who teach the courses. Also, research funding is often tied to provincial initiatives and local industrial requirements (e.g. petroleum industry in Alberta, mining industry in Ontario).

The primary role for CGAC would be to promote awareness of groundwater issues at both the provincial and federal government levels, to ensure that groundwater maintains or increases its profile as a natural resource requiring continued consideration and financial support. This may be in the form of government funding opportunities for universities, influencing specified priorities of agencies such as the Natural Sciences and Engineering Research Council (NSERC) and the National Research Council of Canada (NRC), and the promotion of continuing education. As part of the information available through the CGAC network, the opportunities and specializations in the area of groundwater offered at universities across Canada would be compiled and easily referenced.

Accreditation of groundwater professionals is not consistent across Canada. Some provinces, such as Alberta and British Columbia, have standards analogous to those of Professional Engineer, based on education, work experience, and professional references, that must be attained for the designation of Professional Geologist. Ontario is currently in the process of developing a series of standard or best practices for Professional Hydrogeologists within the newly developed Association of Professional Geoscientists of Ontario (APGO). All provinces should adopt similar professional standards and designation. One of the roles that CGAC could play in this regard would be to assist in the establishment of standard accreditation procedures that would be consistent across Canada, and to facilitate the implementation of individual accreditation programs. Again, this would be done in direct collaboration with provincial authorities, as it is likely that aspects of the accreditation programs will depend on provincial priorities.

Groundwater scientists, located within Canada's universities and federal and provincial research agencies, have two primary roles: 1) development of new knowledge and technologies that help us understand the processes controlling the occurrence and movement of groundwater, groundwater quality, and groundwater contamination; and 2) education of groundwater professionals through university courses. The results of research by groundwater scientists are published primarily in peer-reviewed scientific journals. Groundwater scientists are also trained at Canada's universities, but require a much higher level of training (i.e. a Ph.D.) than do groundwater professionals. The CGAC can have two important roles. First, it could direct municipal, provincial, and federal government agencies and the private sector with specific problems requiring scientific research to the appropriate groundwater scientist in Canada. The CGAC could also work with scientists to gain access to projects that require new scientific research and assist in securing adequate funding for that research. Secondly, CGAC could help foster linkages between those with scientific expertise and those responsible for government policy.

The primary role of groundwater technicians and technologists is to provide quality data and to install groundwater equipment for industry, consulting firms, government agencies, and universities. Their education is typically obtained through a college or university program. In many cases, however, technical people of various backgrounds can develop into groundwater technicians through an appropriate series of short courses that provide training in the necessary skill areas. These short or intensive courses could be co-ordinated through CGAC as described below.

Most provinces require water-well drillers to be licensed. Licensing requirements, however, vary considerably from province to province, and there are only two colleges in Canada that deliver training programs to the water-well industry in Canada: Sir Sandford Fleming College in Ontario and Red Deer College in Alberta. Provincial regulators should co-operate and collaborate to establish standardized qualification, training, examinations, and licensing formats for groundwater drilling across Canada. Also, the Canadian Ground Water Association (CGWA) recommends that water-well drilling should be designated as a trade, with a requirement that specific qualifications are necessary in order to practice. To date, four provinces have the trade designated. In Alberta and New Brunswick, the trade designation is tied to licensing. Acquisition of trade designation is voluntary in British Columbia and Saskatchewan.

The Program Advisory Committee in New Brunswick has recently recommended that the distance-education modules of Red Deer College be accepted as the training standard for New Brunswick water-well drillers. In addition, New Brunswick will use the CGWA certification examinations as the final tests in their program. This is a clear example of province-college-industry collaboration and co-operation. Recent developments have motivated some regulatory agencies to give closer scrutiny to the water-well drilling industry. At the beginning of 2001, the CGWA launched their certification program by delivering examinations to their member water-well drillers and pump installers. Through CGAC, certification of drillers and pump installers could be co-ordinated to ensure that a consistent standard is applied across Canada and that there is easy access for all interested parties to the accreditation guidelines used by different jurisdictions.

One of the primary ways in which CGAC could be involved in training is through short courses and seminars. The CGAC could draw upon the expertise of groundwater specialists in industry, government agencies, and universities to provide specialized training for a variety of scientific, technical, and policy issues. Such training could include:

1) workshops on the results of groundwater research of national relevance (e.g. methods for conducting regional groundwater assessments);

2) technology-transfer sessions on new developments in groundwater technology and equipment (e.g. for water-well drillers and technologists);

3) advanced training for government officials and groundwater professionals (e.g. GIS applications, data-base management, modelling techniques, etc.); and

4) groundwater familiarization training for nongroundwater-focused disciplines (e.g. ministries of Municipal Affairs, Parks Canada, etc.).

The training aspect of the CGAC initiative would have to be very broad and flexible, considering the wide range of requirements of the various stakeholders. The foundation of the training and education programs, however, would be the collaborative structure developed between government agencies, academic institutions, and industry. Sharing of instructional facilities, instructors, and equipment would be necessary for success in this part of the national initiative. Principal groups to target are people in communities and municipalities who are responsible for groundwater issues. Not only does this group deal directly and on a daily basis with groundwater issues in their jurisdiction and have responsibility to the public for the well-being of the groundwater supply, but they often do not have ready access to current training.

7.5 Annex 1 – Alberta Energy and Utilities Board's Oil and Gas Reserve Inventory: a possible model for a National Groundwater Inventory

A National Groundwater Inventory could be modelled after the inventory of oil and gas pools in Alberta. This inventory system was developed by the Alberta Energy and Utilities Board (AEUB; formerly the Energy Resources Conservation Board, ERCB). The system is recognized internationally and has been adopted by many oil-producing jurisdictions in Canada, the United States, and abroad.

In the AEUB system, every oil or natural-gas pool in Alberta with at least one producing well has been identified and mapped. The pools are inventoried by geological horizon and hierarchically grouped into administrative areas known as oil and gas fields. Each pool has average reservoir parameters (e.g. porosity, permeability) determined and tabulated. All wells are assigned to a pool. Volumes of oil, gas, and water produced by every well in production are reported monthly to the AEUB. Industry also submits regular reports on pool pressure, fluid chemistries, etc. to the AEUB. Geological records, petrophysical logs, well-completion details, drill cuttings, and cores for every well drilled must be also submitted to the AEUB. All the raw data enter the public domain. From these data, estimates of original volume of oil-in-place or gas-in-place and remaining reserves in each pool in the inventory are updated and published yearly.

The AEUB uses its inventory of oil and gas pools to execute its regulatory functions. The AEUB also uses the inventory to annually update the Government of Alberta on the province's reserves of nonrenewable oil, gas, coal, heavy oil, and bitumen, as well as forecast future growth or decline trends. Other branches of the Government of Alberta use this information to set policy and to plan for the future. Industry uses the inventory to help in the search for new fossil-fuel reserves.

The pool-inventory system of the AEUB could be used as a model for a National Groundwater Inventory, albeit with

modifications reflecting the differences between groundwater and hydrocarbon resources. In its simplest form, a National Groundwater Inventory would consist of a digital archive of aquifer (i.e. 'pool') maps with linked tabulations of aquifer properties and water chemistry, and annually updated estimates of available groundwater reserves. Each province would maintain its own database of groundwater production, injection, or monitoring wells; completion details; annual production; license information; waste-facility locations; etc. These data, however, would be linked easily to the National Groundwater Inventory through aquifer cross-reference identification numbers. Linkages to surface-water monitoring and management systems may not be practical at present but could be built over time.

7.6 Annex 2 – Geological Survey of Canada's conceptual approach to a National Groundwater Inventory

In an immense country such as Canada, with a wide range of geological, hydrogeological, and climatic regions, a National Groundwater Inventory must be based on groundwater-resource assessments conducted at regional scales. A National Groundwater Inventory can be achieved by integrating a series of quantitative regional assessments into a national inventory. This approach will maximize available resources, since methods, knowledge, and expertise developed in some regions of the country will improve subsequent assessments in other regions. This approach is also a pragmatic way to deal with 1) varied financial and technical resources available across the country; 2) different scopes and methods of assessment that may be required in different regions; and 3) the time required to collect, analyze, and integrate necessary quantitative data. Inventories at the regional (or other) scales must be quantitative if they are to contribute significantly to the sustainable development and management of groundwater resources. Consequently, scientific developments in the quantitative assessment of groundwater resources will be needed.

7.6.1 Regional approach

To improve regional knowledge of Canada's aquifer systems, in light of sparse hydrogeological data, requires a multidisciplinary approach that advances the geological understanding of basins. Basin analysis, which includes mapping and characterizing the reservoir potential of sedimentary basins with methods similar to those used in petroleum exploration, provides an approach that is directly applicable to regional hydrogeological science and assessments.

Basin analysis involves five key steps that directly contribute to a regional groundwater-resource assessment (Sharpe et al., 2002):

1) A necessary prerequisite for regional analysis is database development. Nationally, this will require minimum protocols and a possible checklist for preparing key data layers (e.g. water quality, stream base flow, water-level data), as well as the synthesis of archival and new field data.

2) The next step is to develop primary geological models of the stratigraphy, sedimentary architecture, and depositional system (geological models can similarly be developed for fractured media).

3) These primary elements of the geological framework, used in conjunction with hydraulic testing, will assist hydrogeological conceptualization and model development. Thus, improved understanding of stratigraphic architecture, vertical and lateral sediment variation, and depositional environments provides an improved structure for assigning hydraulic properties to the defined aquifer-aquitard units.

4) Numerical characterization of the regional groundwater-flow system is based on the analysis of combined hydrostratigraphic and chemical information, integrated with recharge, flow, and discharge data.

5) Finally, improved quantitative hydrogeological understanding comes from considering the direct linkages among geological setting, basin history, and aquifer properties and fluxes, so as to yield credible estimates of flow in the regional groundwater system. In this way, sustainable management of groundwater resources will benefit from enhanced data, conceptualization, characterization, quantification, modelling, and understanding of the regional groundwater-flow system.

The work involved in this fundamental basin-analysis approach to regional groundwater assessment could be shared among federal, provincial, municipal, academic, and private-sector partners, following this framework. The approach could be used as a model for a co-operative National Groundwater Inventory, as described in chapter 7.

There have already been various regional assessments of this type at the Geological Survey of Canada: the Oak Ridges Moraine in the greater Toronto region, Ontario; the St. Lawrence Lowlands fractured rock aquifers system north of Montréal, Quebec; the Winnipeg region in Manitoba; and the Maritimes Ground water Initiative in New Brunswick, Prince Edward Island, and Nova Scotia. The Oak Ridges Moraine pro ject is briefly described below, as an example of the application of this approach.

7.6.2 Regional hydrogeology study: the Oak Ridges Moraine, Ontario

The Oak Ridges Moraine (ORM) study has applied basin analysis to a glaciated terrain by integrating data from a variety of sources and scales of investigation to develop a hydrogeological model of the greater Toronto region. This process is being accomplished with funding from, and ongoing collabora tion among, a number of provincial ministries, municipal and local governments, universities, and pri vate-sector partners. This is a good example of collaboration on groundwater.

Substantial progress was achieved in database development and compilation, formulation of a series of conceptual and data-derived geological models, and rendering of a regional three-dimensional (3-D) numeric stratigraphic model. Plans are underway to assist public and private partners in applying these results to develop the groundwater-flow models that are needed, in part, to establish sustainable yields for public water supply. The project has produced 1:20 000 and 1:50 000 scale maps.

These hydrostratigraphic data were complemented with stream base-flow surveys, borehole data, piezometer installation, and water-level monitoring. These data are of value for characterizing flow, for water-table mapping, and for constraining groundwater-flow models. Base-flow and water-well chem istry surveys also helped characterize the flow system and provide information on the evolution of groundwater flow from recharge to discharge areas. Maps of water-table elevation were constructed from water-well records and identification of springs, and combined with the digital-elevation model. Integration of such hydraulic and chemical data into the ORM hydrogeological framework is an ongo ing goal of the ORM basin analysis and flow-system characterization.

A key result of the ORM hydrostratigraphic analysis is the identification of representative hydrogeological settings (e.g. upland aquitards and channel aquifer systems) that have the potential to assist in hydrogeo logical characterization in other regions with similar geological terrain. Despite being a 'well-studied' area, such key hydrogeological settings have not been the subject of much focused hydraulic testing, and, in general, the area requires additional hydrogeological characterization. Due to the teamwork of several collaborators and several years of effort, the stage is set to generate 3-D flow models across the region to assist in sustainable groundwater management and land-use planning, and to further hydrogeological knowledge of the ORM aquifer complex. The ORM study has demonstrated the need for investment in both high-quality data collection and the regional approach that underlies basin analysis, in order to permit a more reliable assessment of groundwater systems in the varied hydrogeological settings across Canada.

7.6.3 Roles

Each participating organization in the National Groundwater Inventory would have its own role, mandate, jurisdiction, and interests that must be recognized and respected. These roles may differ but often overlap. Consequently, collaboration is not only desirable but also often necessary. The Inventory would encourage participants to determine their roles within each regional assessment. For example, the management of water-well records is generally a provincial responsibility, whereas universities and the federal government are often involved in research. In contrast, some activities, such as new data collection, could be contributed by any participating organization. The Inventory would also allow the scope of each regional assessment to be established by the availability of funding, data, and expertise, and to focus on issues relevant to each region.

In summary, the GSC proposes an approach in which a series of quantitative regional assessments are integrated into a National Groundwater Inventory that would contribute to the sustainable development and management of Canada's groundwater resources. This approach would not only make best use of available resources, but also allow all interested parties to contribute to the Inventory while maintaining their roles, mandates, jurisdictions, and interests. Ideally, each regional assessment would include the following steps:

1) Database development

2) Hydrostratigraphic models

3) Aquifer delineation

4) Aquifer hydraulic-boundary conditions

5) Groundwater conceptual-flow models

6) Water-budget analysis in steady-state and transient conditions

7) Numerical hydrodynamic models

8) Assessment of the basin's sustainable safe yield and vulnerability areas

9) Delivery of databases and numerical simulation models to water managers

8 RECOMMENDATIONS

This document identifies goals and outlines strategic directions toward an interagency ***Canadian Framework for Collaboration on Groundwater***. The respective roles and jurisdictions of the provincial and federal governments are respected in this proposed framework, the emphasis of which is placed on the benefits of a co-operative effort among levels of government, partners, and stakeholders. In consideration of growing public concern and enhanced government interest in groundwater, a number of issues of national importance must be addressed to ensure the protection and sustainability of Canada's groundwater resources.

Based on these principles, the National Ad Hoc Committee on Groundwater makes the following recommendations, which are focused in four areas:

1) co-ordination and collaboration mechanisms;

2) national co-operative programs;

3) communication; and

4) performance standards and uniformity across Canada.

With respect to co-ordination and collaboration mechanisms, we recommend:

- establishing a Federal-Provincial Groundwater Committee (FPGC) to enhance co-operation among all levels of government;
- establishing a Canadian Groundwater Advisory Committee (CGAC), representing various stakeholders, to advise the FPGC; and
- annual reporting of the progress of CGAC (FPGC) to stakeholders.

With respect to national co-operative programs, we recommend:

- enhanced funding for groundwater research and inventory;

- undertaking an assessment and inventory of Canada's groundwater resources;
- establishing a groundwater-monitoring 'network of networks';
- identifying critical needs for research on Canadian groundwater issues; and
- promoting linkages between government policy and the research community.

With respect to communication, we recommend:

- programs for raising the public's awareness on their role in protecting groundwater resources;
- providing a knowledge source of groundwater information for groundwater professionals and the public;
- developing and promoting an electronic national groundwater forum; and
- continuing to hold national groundwater workshops every two years.

With respect to performance standards and uniformity across Canada, we recommend:

- advance training to enhance the knowledge and skills of groundwater professionals, well drillers, and technicians across Canada;
- accreditation for groundwater professionals, well drillers, and technicians across Canada;
- acceptance of provincial accreditation of groundwater professionals, well drillers, and technicians across Canada; and
- developing, promoting, and co-ordinating guidelines for best-management practices and technology transfer relating to groundwater.

9 ACKNOWLEDGMENTS

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The groundwork for this report is the sole responsibility of the National Ad Hoc Committee; its full preparation and completion, however, benefited greatly from interaction with various liaison groups representing each of the original members. These groups included individuals from the provinces, the Yukon Territory, federal departments, industry, consulting firms, universities, and other nongovernment organizations. The support of all of these individuals and their respective agencies made this effort possible. The report is the product of consultations across Canada and of the two national workshops on groundwater.

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11 APPENDIX 1 – SUMMARY OF LOOMING GROUNDWATER ISSUES IDENTIFIED DURING THE FIRST NATIONAL WORKSHOP ON GROUNDWATER (2000)

11.1 General synthesis of the workshop

The objectives of the First National Workshop on Groundwater were to:

- assess current knowledge regarding the aquifers in the main regions of Canada;
- evaluate the state of those aquifers by identifying issues and stresses to which they are exposed;
- identify, on a broad basis, problems common to different aquifers, as well as specific regional problems; and
- initiate a dialogue among provinces and federal agencies.

The main **conclusions** were as follows:

- Participants stressed the importance for Canada of understanding its groundwater quantity and quality, and expressed the need for a better co-ordination and collaboration at the federal level, and between federal and provincial agencies. The creation of an advisory or co-ordinating committee that would include federal and provincial agencies was suggested. The idea of a Memorandum of Understanding between Natural Resources Canada and Environment Canada, concerning federal research on groundwater resources, also emerged from the meeting.
- Concerns were expressed regarding the lack of adequate funding dedicated to research, monitoring, and reporting, as well as concerns about the lack of complete, accurate, and updated data and general information on Canada's groundwater that is readily available to the public.
- Several issues were identified and potential collaboration among provinces and federal agencies were discussed. Reactivation of the national steering committee for groundwater was proposed as a possible mechanism for co-ordination. The creation of an advisory or co-ordinating committee that would include federal agencies and provinces was explored.

The main recommendations were to:

- produce a national groundwater inventory;
- reactivate or create a national steering committee on groundwater;
- create, in close co-operation with the provinces, a national groundwater-monitoring network;
- investigate the means for obtaining adequate financial resources;
- perform specific groundwater research (a list of 15 subjects was compiled); and
- organize a similar national workshop very year or two.

11.2 Items specific to provinces and territories

11.2.1 British Columbia

11.2.1.1 General issues

- Groundwater supplies 22% of the population with drinking water
- British Columbia's groundwater use represents 23% of national use by volume
- Groundwater use is unregulated
- Deficiencies with data quality and data capture
- Integration of quantity and quality data
- Georeferencing of groundwater data for GIS applications

11.2.1.2 Quantity issues

- Conflicts between groundwater and surface-water users, including well interference and groundwater use on surface-water licenses, fisheries habitat, and wetlands, unregulated well use and unregulated well drilling, uncontrolled flowing wells

11.2.1.3 Quality issues

- Contamination by nutrients such as nitrates
- Natural sources of contamination such as arsenic and fluoride
- Unregulated standards for water wells
- Localized saltwater intrusion in coastal areas
- Chemical spills and non-point source pollution (NPS)

11.2.1.4 Current and future activities

- Public education and awareness
- Data gathering and well inventory
- Observation-well network of 163 stations
- Aquifer delineation and classification
- Establishing partnerships for protection initiatives
- Guidelines for well construction, well testing, well protection, and water conservation
- Promote well- and aquifer-protection planning

11.2.2 Alberta

11.2.2.1 General issues

- Aquifers are under stress
- Delineation and characterization of aquifers is costly and problematic

11.2.2.2 Quantity issues

- Evidence of hydraulic connection of groundwater and rivers
- Difficult to quantify groundwater–surface water interaction
- Monitoring is costly

11.2.2.3 Quality issues

- Quality problems due to septic systems
- Mixing of groundwater of differing qualities
- Need for research into the presence of arsenic in Quaternary sediments and bedrock, which appears to be of natural origin
- Septic systems are heavily used

11.2.2.4 Current and future activities

- Evaluate the long-term potential health effects from groundwater containing arsenic
- Evaluate the effects of potential contamination of the regional aquifer system by arsenic of industrial origin

11.2.3 Saskatchewan

11.2.3.1 General issues

- 30 to 40% of the population relies on groundwater, the majority being rural residents and communities
- Industrial and agricultural purposes (livestock operation, oil industry, power generation)
- Public becoming more involved and showing a lack of confidence toward industry and government

11.2.3.2 Quantity issues

- Aquifer stresses vary from minor to extreme
- New large developments are now controversial
- Intensive livestock operations are a major issue in many areas

11.2.3.3 Quality issues

- Limited financial and technical resources, resulting in limited data and information concerning groundwater quality
- Lack of administrative co-ordination
- Need to uptake and enforce legislation

11.2.3.4 Current and future activities

- There are currently four management plans involving stakeholders and government agencies
- Groundwater mapping, database development, monitoring, and land-use planning

11.2.4 Manitoba

11.2.4.1 General issues

- Groundwater supplies ±20% of the population with drinking water; most of the rural population relies on groundwater as a source of drinking water
- Groundwater use is regulated (uses greater than 25 000 L/day require water-rights licence)
- Monitoring water-level network of more than 550 active stations, quality network of approximately 150 wells sampled on annual or more frequent basis, a greater number on a less frequent basis; during 1999–2000, 1000 supply wells were sampled for quality
- Water Planning and Development is implementing aquifer management plans
- Several government departments/branches have responsibilities for various aspects of groundwater (capacity, licensing, protection, development, permits, health)
- Digital database of approximately 90 000 logs and at least some chemistry for 10 000 wells
- Regional groundwater mapping completed in the 1980s at 1:250 000 scale for Agro-Manitoba; aquifers mapped in 3-D and major-ion chemistry of groundwater completed
- Province has a good handle on distribution of major sand and gravel aquifers and bedrock aquifers, and on the general water quality in these aquifers

11.2.4.2 Quantity issues

- Aquifer capacity evaluations have been done for major sand and gravel aquifers and portions of major bedrock aquifers
- Some aquifers and basins are fully allocated because of recent 'wet' weather cycle; allocated basins are at or near record high water levels
- High quantity/quality aquifers are not uniformly distributed and development is not uniform
- Still some challenging issues involving potential influx of poor-quality (saline) water laterally or from above due to increasing development
- Recharge processes and rates poorly understood for bedrock aquifers and buried sand and gravel aquifers

11.2.4.3 Quality issues

- Based on 1999–2000 sampling of approximately 1000 private water wells, 16% of rural wells are above Canadian Drinking Water Guidelines for nitrate and 42% of rural wells test positive for coliform bacteria, including 3% for *E. coli*
- Saline groundwater-well penetration, mixing water between saline and nonsaline aquifers
- Well-head protection in flood-prone areas
- Since 2000, 19 boil-water advisories have been issued by the province for communities, campgrounds, or cottage developments
- Natural water-quality concerns regarding salinity, boron, uranium, sulphate, (?)selenium, arsenic, manganese, fluorine, and barium
- Well construction: lack of formal well-head protection and recharge-zone protection
- Localized flooding, high water table, and malfunctioning septic systems
- Intensive livestock operations: manure storage and spreading
- Point-source spills and leaks: hydrocarbons, DNAPLs, pesticides, unlined historic landfills
- Non-point sources: agricultural fertilizers, chemicals, manure

11.2.4.4 Current and future activities

- Monitoring of quantity through a groundwater network and quality through the Manitoba Rural Groundwater Quality Initiative (MRGQI; rural private wells and a groundwater network)
- Protection (management recommendations regarding new or expanding intensive livestock operations (ILOs)
- Drinking Water Advisory Committee Report issued by the Office of the Chief Medical Officer of Health in November 2000
- All well drillers are licensed; required to submit stratigraphic-log and well-completion information; addressing issue of mandatory certification
- Revamping Ground Water and Water Well Act
- Provincial bacterial testing program initiated in 2001; province covers 70% of the cost of private well-water bacterial analysis
- Mandatory certification program for operators of water-treatment plants, beginning in fall of 2001
- Data collection, dissemination
- Aquifer-management plans (3 in various stages of planning/completion)
- Well-sealing program for abandoned wells in the Red River flood plain
- Funding of conservation districts (13 existing and 3 under development) for watershed-based, sustainable soil and water management
- Education programs and establishing information sources (updated drinking-water fact sheets)

11.2.4.5 Wish list items

- Mapping of buried valleys
- Placing intertill or intratill aquifers in the Pleistocene stratigraphic framework
- Regional groundwater maps converted to GIS format and updated every few years as more information becomes available
- Improvements in capabilities for using well logs and chemistry in GIS and cross-sections
- Better understanding of thermal exchange and capacity of bedrock aquifers
- Improved understanding of water and contaminant-transport processes in low-permeability till and clay deposits in the province
- Important to understand that, at the moment, none of these issues could be considered urgent and in need of immediate accomplishment; generally, these are long-term goals that can be accomplished with a modest increase in resources

11.2.5 Ontario

11.2.5.1 General issues

- Challenges faced over the last 20 years have underlined the need for the province to maintain its monitoring programs and databases for the development of sound policy
- Public demand for groundwater is continuing to escalate with population growth, climate change, and an increasing global thirst
- Management of the resource must involve all major stakeholders

11.2.5.2 Quantity issues

- Competing interests and priorities among agriculture, municipal needs, recreation, and natural habitats
- 23% of Ontario's population depends solely on groundwater as a source of drinking water
- Approximately 750 000 water wells provide 1 400 000 m/day for drinking-water purposes
- 90% of farms rely on groundwater for irrigation of 40 250 ha of cropland

11.2.5.3 Quality issues

- 35% of rural wells are contaminated because of agricultural impacts
- 34% of septic systems are malfunctioning and release chlorides, nitrate, sodium
- Road-salting activities
- 35% leakage in single-lined underground storage tanks
- Unlined historic landfills release metals, volatile organic compounds, nitrate, pesticides
- Spills and leaks
- Unregulated sites and industries release chlorinated solvents

11.2.5.4 Current and future activities

- Monitoring (data collection, mapping, modelling, interpretation, dissemination)
- Regulation, policy, and guidelines revision and development
- Enforcement in well construction and maintenance, spills, and water supply and quality interference

11.2.6 Quebec

11.2.6.1 General issues

- Laws and regulations do not always account for real or potential uses of groundwater and its relation with surface water
- Few municipalities have delimited a protection area around wells or consider groundwater as a resource
- Economic development of communities increases water needs
- Misunderstanding of the resource leads to concerns among the public, which can jeopardize development

11.2.6.2 Quantity issues

- 20% of the population relies on groundwater as a source of drinking water
- Groundwater is the preferred water resource in 90% of the inhabited parts of the province, because of its quality and proximity

11.2.6.3 Quality issues

- In some areas, groundwater quality has deteriorated because of industries and agriculture
- In 1996, the government adopted the *Projet de politique de protection et de conservation des eaux souterraines*, a project that recognizes groundwater as a collective resource and protects it against abusive use and pollution

11.2.6.4 Current and future activities

- Minimum standards for water-well construction
- For drinking-water wells, obligation to establish the wellhead recharge area and assess groundwater vulnerability
- Necessity to obtain government approval for important groundwater-withdrawal projects
- Establish a program to improve knowledge regarding groundwater resources
- Establish a water management policy

11.2.7 New Brunswick

11.2.7.1 General issues

- Just over 60% of New Brunswick residents rely on groundwater for drinking water
- Recently introduced Municipal Wellfield Protection Program will affect 55 municipalities in the province
- Integration of a water management-allocation strategy with watershed management
- Overall commitment to clean and plentiful drinking water for New Brunswick residents

11.2.7.2 Quantity issues

- Conflicts among groundwater users in the province
- Better knowledge needed of the resource and its controlling factors
- Climate-change impacts and the possible establishment of drought indexing
- Establishing a better understanding of the connection between groundwater and rivers

11.2.7.3 Quality issues

- Natural sources of contamination such as arsenic and uranium
- Better knowledge needed of the resource and its controlling factors
- Localized saltwater intrusions in coastal areas
- Assessment and mitigation of non-point-source impacts

11.2.7.4 Current and future activities

- Public education, awareness, database management, and thematic mapping
- Re-establishing the Groundwater Observation-Well Monitoring Network
- Establishing partnerships for aquifer delineation and characterization
- Integration of land-use planning activities with groundwater management and protection programs
- Conducting a review of the recent domestic water-well sampling pilot program (summer 2001)
- Placement of regional water-planning officers

11.2.8 Nova Scotia

11.2.8.1 General issues

- Shallow bedrock conditions
- Water table close to surface (3–6 m)

- High annual precipitation rates (1300 mm)
- Local groundwater-flow systems

11.2.8.2 Quantity issues

- 50% of population relies on groundwater
- 36% of municipal water supplies are from groundwater sources
- 2500 to 3000 new wells constructed each year

11.2.8.3 Quality issues

- Depend on rock type, presence of metals, low pH, salt, SO, sediments
- Road salt
- Seawater intrusion
- Nitrates and pesticides
- Hydrocarbons and DNAPLs

11.2.8.4 Current and future activities

- Ambient monitoring
- Improvements in data management
- Groundwater mapping and aquifer identification
- Research and educational programs

11.2.9 Prince Edward Island

11.2.9.1 General issues

- The province depends 100% on groundwater
- Land area is 50% forested and 35% agricultural
- Cool humid climate with annual precipitation of 1100 mm
- Bedrock composed essentially of Upper Carboniferous 'red-bed' sandstone sequence
- Aquifers are unconfined or semiconfined in fractured porous media

11.2.9.2 Quantity issues

- Recharge amounts to approximately 25 to 35% of annual precipitation
- Groundwater discharge accounts for 55 to 65% of mean annual stream flow
- Wells are of simple 'open hole' construction

- Approximately 55% of the population relies on private wells
- Excessive groundwater extraction in some basins has had a significant impact on stream-flow regimes
- Demand for groundwater for agriculture and golf-course irrigation is constantly growing
- Current groundwater allocation is not fully consistent with protection of maintenance flow in streams

11.2.9.3 Quality issues

- Few 'natural' groundwater-quality problems
- Saltwater intrusion occurs locally along the coastline, although the extent is highly variable and difficult to predict
- Nitrate levels in groundwater are elevated and continuing to increase
- Indirectly, nitrate levels increase nutrient supply to estuaries and contribute to eutrophic conditions

11.2.9.4 Management issues

- Various monitoring activities: maintenance of a network of observation wells; data collection based on 'index basins'; database on water wells, GIS technology to capture and retrieve data
- High-capacity wells are approved under a two-step process: 1) review of proposed groundwater development and assessment of required data, and 2) allocation of permissible withdrawal volume
- Assessment of groundwater extraction is based on 1) performance of wells relative to intended use, 2) predictive impacts on adjacent groundwater users, and 3) overall water-balance considerations and impact on stream flow
- Groundwater allocation process is under review, particularly in relation to impact on stream base flow

11.2.9.5 Current and future activities

- Development of practical wellfield protection strategies
- Mitigation of agricultural impacts on water quality, especially with regard to nitrate
- Assessment of possible impacts relating to climate change

11.2.10 Newfoundland and Labrador

11.2.10.1 General issues

- Major effort since Walkerton to identify and sample all public water supplies for bacteria and chemicals; unlike most other provinces, the provincial government, rather than the municipalities, has decided to assume responsibility for sampling and reporting of results; report entitled *Source to Tap* outlines the scope and current status of various government programs relating to drinking-water safety
- Approximately 27% of province, mostly in rural areas, depends on groundwater as a source of drinking water
- There are 293 identified public groundwater supplies, mostly small (serving from 5 to 50 homes)
- Groundwater observation wells maintained on the island part of the province

11.2.10.2 Quality issues

- Nuisance chemicals such as iron, manganese and hydrogen sulphide are the main problem with groundwater quality in the province
- As expected, there is no problem with trihalomethanes in groundwater sampling done to date
- Saltwater intrusion is factor with some coastal areas

11.2.10.3 Quantity issues

- Most wells are completed in bedrock and yield less than 10 L/min; larger towns such as Stephenville and Happy Valley-Goose Bay have multiple wells drilled in overburden deposits
- Depletion of groundwater resources not an issue due to low population and dispersion of communities

11.2.10.4 Current and future activities

- Increasing the number of designated wellhead protection areas, especially for the larger public groundwater supplies
- Chemical sampling has commenced for about 80 schools with their own water supply (a well in almost all cases)
- Regular source-water sampling of about 50 water supplies ongoing
- Risk analysis (of contamination) desired for all public water groundwater supplies
- Development of newspaper articles on proper well maintenance
- Seminar for well drillers planned for after 2002
- Report needed on hydrogeology of the province
- Update Web site

11.2.11 Yukon Territory

11.2.11.1 General issues

- Wells have recently gone dry; is it because of climate change or overutilization?
- There are no monitoring stations in Yukon Territory
- Groundwater and subsurface processes are poorly understood
- The Yukon Territory is largely underlain by discontinuous and continuous permafrost

11.2.11.2 Quantity issues

- A large proportion of communities rely on wells as their water supply
- Whitehorse uses a mixture of surface water and groundwater to assure a water temperature above 4°C in winter and to reduce turbidity in summer

11.2.11.3 Quality issues

- There is potential contamination of groundwater at abandoned mine sites, aging fuel-storage depots, and sewage-treatment facilities
- Industrial development and population expansion in rural zones is also a concern for water quality

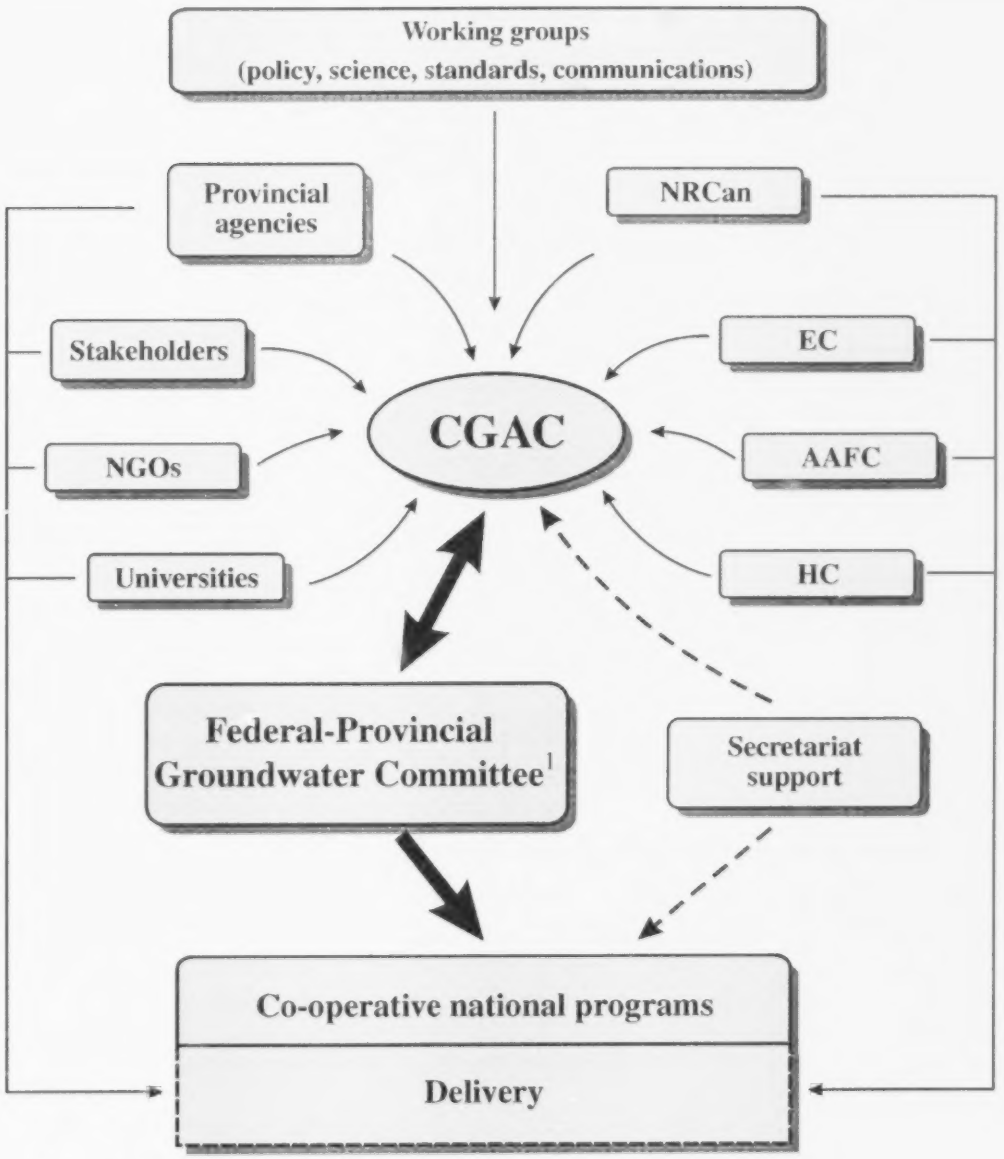
11.2.11.4 Current and future activities

- Groundwater study, including a database pilot project on private wells
- Establishment of a working methodology (log purchase, database construction, geology, questionnaire)
- Hydrogeological characterization of aquifer types, groundwater-flow conditions, and areas of recharge and discharge
- Future work will include database expansion, water-balance study, water-quality study, and public awareness and education
- Eventually develop and implement legislation and mechanism to obtain water-well records on a routine basis

12 APPENDIX 2 – ORIGINAL MEMBERS OF THE NATIONAL AD HOC COMMITTEE ON GROUNDWATER

Name	Affiliation	Stakeholder group
Al Kohut	Manager, Groundwater Section, Water Management Branch British Colombia Ministry of Water, Land and Air Protection (250) 387-9465 Al.kohut@gems7.gov.bc.ca	British Columbia
Nolan Shaheen	Manager, Hydrogeological Services Saskatchewan Water Corporation (306) 694-3963 nshaheen@saskwater.com	Prairies
Cam Baker	Senior Manager, Sedimentary Geoscience Ontario Geological Survey Ministry of Northern Development and Mines (705) 670-5902 cam.baker@ndm.gov.on.ca	Ontario
Michel Ouellet (as observer)	Manager, Direction des politiques du secteur municipal Quebec Ministry of the Environment (418) 521-3885 ext. 4852 didier.bicchi@menv.gouv.qc.ca	Quebec
Darryl Pupek	Environmental Evaluation Section New Brunswick Department of Environment and Local Government (506) 453-3656 darryl.pupek@gnb.ca	Atlantic (Newfoundland and Labrador, Prince Edward Island, New Brunswick, Nova Scotia)
Dave Rudolph	Professor, Department of Earth Sciences University of Waterloo (519) 888-4567, ext. 6778 drudolph@uwaterloo.ca	Universities
Maurice Lewis	Executive Officer Canadian Ground Water Association (403) 749-2331 cgwa@agt.net	Industry, consultants, nongovernment organizations
Allan Crowe	Chief, Integrated Watershed Management and Modelling, National Water Research Institute Environment Canada (905) 336-4585 allan.crowe@cciw.ca	Federal
Alfonso Rivera	Chief Hydrogeologist, Geological Survey of Canada Natural Resources Canada (418) 654-2688 arivera@nrcan.gc.ca	Federal

13 APPENDIX 3 – STRUCTURE OF THE CANADIAN GROUNDWATER ADVISORY COUNCIL (CGAC)



[1] strong links to Canadian Council of Ministers of Environment (CCME) and National Geological Surveys Committee (NGSC)

MEMBERS OF THE EXTENDED NATIONAL AD HOC COMMITTEE

Cam Baker[1]
Ontario Geological Survey
Ontario Ministry of Northern Development and Mines

Bill Banks
Waterloo Hydrogeologic Inc.
Ontario

Dave Briggins
Nova Scotia Environment and Labour, and Canadian Council of Ministers of the Environment

Allan Crowe[1]
National Water Research Institute
Environment Canada

Keith Guzzwell
Newfoundland Department of Environment

Steve Holysh
International Association of Hydrogeologists
Ontario

Richard Janowicz
Water Resources Division
Indian and Northern Affairs Canada
Yukon

Al Kohut[1]
British Columbia Ministry of Water, Land and Air Protection

Kevin Parks
Alberta Geological Survey
Alberta Energy and Utilities Board

Graham Phipps
Water Branch
Manitoba Conservation

Darryl Pupek[1]
New Brunswick Department of Environment and Local Government

Rick Richardson
National Geological Surveys Committee
Alberta

Alfonso Rivera[1]
Geological Survey of Canada
Natural Resources Canada

Dave Rudolph[1]
Department of Earth Sciences
University of Waterloo

Nolan Shaheen[1]
Saskatchewan Water Corporation

George Sommers
Prince Edward Island Department of Fisheries, Agriculture and Environment

Maurice Lewis (deceased)[1]
Canadian Ground Water Association
Alberta

Jerry Topilka
Canadian Ground Water Association
Alberta

[1] Original Ad Hoc Committee member